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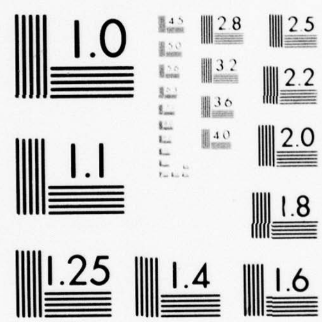

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CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

EXPERIMENTAL STUDY OF THE DYNAMICS OF VARIABLE-LENGTH CABLE SYSTEMS

April 1979

An Investigation Conducted by

GRADUATE AERONAUTICAL LABORATORIES
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

N68305-76-C-0033

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Laboratory experiments on the dynamics of variable length cable systems are described. The prototype situation that these experiments simulate is the deployment of retrieval of a heavy object at sea. A winching mechanism attached to an electromechanical oscillator was mounted over a 65 ft. (20 m) deep tank of water. A mass suspended by elastic and inelastic cables was

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payed-out and reeled-in at specified velocities and accelerations while being oscillated in the vertical plane. Cable tension data are provided as a function of cable direction, length, velocity, acceleration, and the frequency and amplitude of the oscillator.

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I. INTRODUCTION

The Navy's Civil Engineering Laboratory is engaged in a major program of research into the dynamic behavior of cables and cable structures in the ocean. A key objective of this program is the development of mathematical models to predict the large amplitude dynamic response of cable structures during implantment, recovery, or while in-situ. An extensive experimental program is being conducted to provide data for verification of the predictive models. This report covers laboratory-scale experiments which have been conducted as part of this program.

The tests were conducted in the Hydrodynamics Laboratory of the Graduate Aeronautical Laboratories, California Institute of Technology, during the period 17 November through 5 December 1977. The model assemblies tested consisted of a 2 in. (50.8 mm) diameter sphere weighing 1.003 lb. (455.4 g) in water supported by an elastic (soft rubber) or an inelastic (braided nylon) cable. These assemblies were oscillated in water at rates of 0.0 to 3.0 Hz and at amplitudes of 0.0 to 1.0 in. (25.4 mm). The direction, velocity, and acceleration of the cable was controlled over a wide range of values. Cable tension data were recorded as a function of cable direction, length, velocity, acceleration, and the frequency and amplitude of the oscillatory motion.

A description of the experimental program, the apparatus, procedures, and typical results are provided in this report. Complete data are provided in supplemental volumes, see Reference 3.

II. DATA FEATURES

A summary of the tests conducted is provided in Table 1, "Index of Tests". The data taken during the experiments are presented in English and Metric (cgs) units in tabular and in plotted form in a supplement. The increment and magnitude of the scales displayed in this report have been held constant to provide a common basis for comparison. Analysts interested in varying the presentation of the data may resort to a data tape described in the report.

Data are provided demonstrating damping, phase shift, and resonance of the cable systems tested; these are of sufficient accuracy to permit verification of the predictive models.

III. EXPERIMENTAL APPARATUS AND PROCEDURES

A schematic drawing of the experimental arrangement is provided as Fig. 1. An electro-mechanical oscillator was attached to the upstream leg of the High Speed Water Tunnel (Ref. 1) at a large port located on the operating level. As the tunnel was not in operation, this leg served as a 65 ft (19.8 m) deep, 5 ft (1.52 m) diameter tank of water in which the experiment was conducted.

A. Electro-mechanical Oscillator

An electro-mechanical oscillator was used to excite the model cable assemblies in the vertical, or heave, direction. The oscillator, which was designed, fabricated, and instrumented as a part of the experiment, is capable of providing the following motions;

Amplitude: 0.0, 0.1, and 1.0 inch
(0.0, 2.54, and 25.4 mm.)

Frequency: Continuously variable from 0.0 to 3.0 Hz.

A side view of the oscillator is shown in Fig. 2. An arrangement drawing identifying the components is provided as Fig. 4. Basically, the oscillator consists of two slider plates driven by eccentric pins. The pins may be positioned on the output shaft of two right angle gear boxes to give the desired amplitude. The gear boxes, Fig. 3, are driven by a shaft connected to a 1/3 HP variable speed motor. Two slider plate mechanisms were used to provide accessability to the winching mechanism, which was located outside the tunnel riser, to position the cable tension transducer on the centerline of the riser,

and to reduce the reciprocating mass of the assembly. A top view of the assembly indentifying these components is provided as Fig. 5.

B. Winch Mechanism

The cable winch mechanism was fixed to the left hand slider plate as illustrated in Fig. 2. A 1/8 HP variable speed motor was used to drive the capstan. The cable path may be traced in Fig. 4. Cable direction, run time, velocity, and acceleration could be controlled over the following range:

Direction: "Pay-out" or "reel-in"

Run Time: 0.0 to 300 sec

Velocity: Variable from 0.0 to $\pm$ 2.0 ft/sec,
(0.0 to $\pm$ 0.610 m/sec)

Acceleration: Variable from 0.0 to $\pm$ 4.0 ft/sec^2
(0.0 to $\pm$ 0.914 m/sec^2.)

C. Instrumentation

Two classes of instrumentation were employed during the experiment. The first was used to set up and monitor the experiment and the second was used to create a permanent record.

1. Monitoring Instruments

The frequency of the oscillator was set and monitored through the use of a magnetic proximity pick-up which was excited by a sixty-tooth gear attached directly to the output shaft of the oscillator drive motor. The amount of cable payed out at the start of a run was determined through the use of a mechanical revolution counter driven by a 1.00 ft. circumference wheel in direct contact with the cable. Cable velocity, acceleration and run time were set using a commercially

fabricated motor control system. Feed-back for this system was provided by a tachometer attached directly to the output shaft of the capstan drive motor.

Signals from these instruments, and others described below, were recorded on a direct writing galvanometer recorder. These temporary analog records were used to verify the successful completion of each test.

2. Recorded Instruments

Five parameters were instrumented and permanently recorded. These parameters are:

<u>1</u> Cable length,

<u>2</u> Cable velocity,

<u>3</u> Cable acceleration,

<u>4</u> Cable tension, and

<u>5</u> Oscillator phase angle.

A schematic of the instrumentation system is provided as Fig. 6. Table 2 lists the transducers used and provides specifications.

Cable length was measured through the use of a helical potentiometer driven by the 1.00 ft circumference wheel described above. Zero was taken at the point where the end of the cable-anchor assembly just cleared the tension transducer sheave.

Cable velocity data were provided by a separate instrumentation quality tachometer driven by the capstan drive motor.

Cable acceleration data were provided by a differentiator circuit attached to the output of the velocity tachometer. A schematic of this circuit is provided as Fig. 7.

Cable tension was measured by a strain gage load cell which supported a sheave at the right end of the cable path illustrated in Fig. 4. Cable tension is taken as positive when a load is applied which tends to increase the length of the cable.

The phase angle of the oscillator was measured through the use of a rotary potentiometer attached to the slider drive shaft, see Figs. 3 and 5. Zero phase angle was taken as the top-dead-center position of the slider plate.

These data, along with a voice log and switch trace used to identify the tests, were recorded on a seven track analog magnetic tape recorder. The analog tapes were later digitized as part of the data reduction procedure described below.

D. Models

Two model assemblies were tested. The assemblies consisted of an elastic cable supporting a small anchor and a second inelastic cable supporting the same anchor.

1. Anchor

The model anchor was a 2.010 ± 0.010 in (51.05 mm) diameter sphere weighing 455 grams in water. The outside of the sphere was painted with an alternate black and white pattern dividing the surface into eight zones of equal area (see Figs. 2 and 3). The cables were attached to the anchor by means of a fishing tackle snap swivel which hooked into a small stud projecting from the surface of the anchor.

2. Elastic Cable

The dynamic response of an elastic system was simulated through the use of a soft rubber cable attached to the anchor. The mechanical properties of this cable are provided in Table 3. The notation used in the load vs. deflection data found in this table, and also in Table 4, is as follows:

L = the length of the cable as measured immediately following the application of the load

L_1 = the cable length approximately one minute following the application of the load

ΔL = the change in L between loadings including creep.

A plot of the elastic characteristics is provided as Fig. 8. As this material is plastic, any stress-strain curve obtained from these data must be considered an approximation.

3. Inelastic Cable

The response of an inelastic system was simulated through the use of a braided nylon line attached to the anchor. This cable had approximately four times the axial stiffness of the rubber cable. Mechanical properties of this cable are provided in Table 4.

A series of three load-deflection tests were conducted on a six foot specimen of nylon line after being pre-conditioned as follows. First, the line was soaked in water for twenty-four hours. After removal one end was fixed and the other attached to a weight pan. Next, the line was exercised fifteen times by repeatedly loading it with a two pound weight. The results of all three tests are provided in Table 4. Plots of the data are provided as Fig. 9.

Measurements were also made to determine the effect of water immersion on the elongation of the cable under steady load (i.e., "creep"). These data are provided in Table 5.

E. Procedures

Many of the procedures, e.g., setting the oscillator amplitude and frequency, are trivial and are not described. Other less obvious procedures are described below.

1. Pre, and Post-run data

Two time columns appear in the tabulated data of Appendix I. The first, "RCDR TIME SEC" for record time in seconds, is the length of the record. Recordings of the signals from all the instruments were made for approximately 10 sec prior to, and following, the pay-out or reel-in of the cable. These records provide cable tension data which results only from the motion of the oscillator.

The second time column, "RUN TIME SEC" for winch running time in seconds, is the duration of the pay-out or reel-in motion of the winch capstan.

2. Winch velocity profile

The winch was run through a preprogrammed velocity profile for each test. The profile consisted of the following three phases:

a. Acceleration Phase: The capstan, and cable, were accelerated at a fixed rate until the winch tachometer indicated the desired cable velocity had been achieved.

b. Constant Velocity Phase: After the desired velocity was obtained, the capstan was driven at constant velocity for a specified amount of time.

c. Deceleration Phase: When the constant velocity phase was completed, the capstan was decelerated at a constant rate until the cable was brought to a stop.

The accelerations, velocities, and decelerations used are identified in Table 1. A zero is sometimes listed in the "Dec" or deceleration column. This indicates a "Crash Stop." The crash stop, which simulates an emergency stop or jamming of the winch, was achieved by bringing the capstan to a halt with the dynamic breaking capability of the winch motor control.

3. Initial cable length setting

The tests were run in pay-out/reel-in pairs for which data were taken during the pay-out phase and again for the reel-in phase. The procedure used to set the initial value of cable length was as follows:

a. The cable was set on the oscillator so that the anchor hung just below the tangent point on the tension transducer sheave.

Next the 1.00 ft. circumference measuring wheel was brought in contact with the cable and the mechanical footage counter set to zero. At this time the helical potentiometer which provided the cable pay-out length signal was moved 1/4 turn off the zero stop. This 1/4 turn bias, which corresponded to an indicated cable length of 2.2 ft., provided a margin of safety. In the event the cable was pulled through the tension transducer, the helical potentiometer would not be run against its stop and the possibility of damage was avoided. As a result, 2.2 ft. (67.1 cm) must be subtracted from the tabulated length values to arrive at the length of cable deployed.

b. The cable was then winched out until the mechanical counter indicated the "initial length" required by the test plan. For the majority of the pay-out runs this was 5.0 ft. At this time the helical potentiometer indicated 7.2 ft. and the bottom of the anchor was 3 feet below the water surface.

c. The test was run by running the winch through the pre-programmed pay-out velocity profile and the anchor would be lowered through the water.

d. The cable was next winched in or out until the mechanical counter indicated the desired initial length for the reel-in test phase.

Elongation of the elastic cable following pay-out was observed. On one occasion the mechanical counter was used to winch out 20 feet of elastic cable. Next, an indicated 20 ft. of cable was winched in. The amount of cable remaining in the water, when measured with a steel tape, was found to be 11 ft. 7 in. This elongation is unavoidable and is a result of the fact that unstretched cable is payed-out while

stretched cable is reeled-in. The stretching, which is time dependent, is caused by the weight of the anchor, the distributed cable weight, and creep. The actual and indicated cable length were brought into agreement prior to the pay-out phase of each run.

Note that on the occasion cited, where large stretching occurred, a 455 gram anchor was used and the time period involved from initial pay-out to reel-in was approximately two minutes. In order to reduce this stretching during the elastic cable tests the anchor weight was limited to a maximum of 150 grams and the time duration of a given test held to order one minute.

F. Data Reduction and Accuracy

Analog signals from the transducers were recorded on magnetic tape during the experiment. These records were later digitized and stored on digital tape in the format described in Appendix I. Tare corrections, including a dynamic tare to eliminate the effect of the tension transducer sprung mass, and calibration factors were applied to the data through the use of the FORTRAN program provided in Appendix I.

The tables and figures provided in the data supplement to this report, and Table 6 and Fig. 10 of this report, are the result of this computer-based data reduction technique.

Steady-state excitations were applied to each transducer separately to verify the specified accuracy of the instrument. In addition, an end-to-end calibration was performed in which each transducer was excited with a known input and a comparison was made with the final computer generated output. The results of the over-all calibration are as follows:

Cable length: 0.1 ft or 0.8% of indicated value, whichever is greater

Cable velocity: $\pm$ 2% of indicated value

Cable acceleration: $\pm$ 5% of indicated value

Cable tension: $\pm$ 1% of indicated value

Oscillator phase angle: $\pm$ 2.5 deg

The assessment of the cable velocity and acceleration precision is not as certain as the other parameters due to the difficulties inherent in establishing known steady-state velocity and acceleration standards.

IV. PRESENTATION OF RESULTS

The data taken are presented in the form of tables, plots, and a digital data tape. Table 6 and Fig. 10 of this report are typical of the data taken. Complete tabular and plotted data are available as a data supplement to this volume. The data tape is available upon request, Ref. 2.

A. Tables and plots

A 0.1 sec time interval was used as a time base in both the tabular and plotted data. Further, a five lb tension scale range and a 120 sec record time were selected for the plotted data. These ranges have been held constant in all the data presented here to provide a common base for comparative purposes.

B. Data Tape

Analysts interested in varying the format of the results (e.g., to reduce the interval of the time base) are referred to a digital magnetic data tape, Ref. 2, on which the data have been recorded at a rate of 1,000 samples per second per channel. The tape format, and a FORTRAN language program used to control the output, are described in Appendix I.

ACKNOWLEDGEMENTS

This experiment was carried out under the sponsorship of the Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, California, Contract No. N68305-76-C-0033. The Navy was represented by Mr. Dallas J. Meggitt, program manager and initiator of the experiments, Mr. Earl F. Buck, who was present throughout the experimental portion of the program, and Mr. Steve Sergev and Dr. Francis C. Liu who were present during portions of the program and made technical contributions.

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1. Ward, T.M. "The Hydrodynamics Laboratory at the California Institute of Technology", Journal of Fluids Engineering. Trans. ASME, Dec. 1976, pp. 740-748.

2. "Variable Length Cable Dynamics", Data Tape available from CEL.

3. Ward, T.M. "Experimental Study of the Dynamics of Variable-Length Cable Systems," Supplement Volume I, CEL CR 79.007; Supplement Volume II, CEL CR 79.008; Supplement Volume III, CEL CR 79.009, Apr. 1979.

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TABLE 1

INDEX OF TESTS

			WINCH PARAMETERS						OSCILLATOR PARAMETERS		
Test No.	Cable Matl.[1]	Dir.[2]	Acc. ft/sec²	Vel. ft/sec	Dec. ft/sec²	Run time sec	Initial length ft	Final length ft	Mode[3]	Amp. inch	Freq. Hz
1	N	PO	0.25	0.50	0.25	117	5.00	49.70	S	0	0
2	"	RI	"	"	"	"	55.10	11.75	"	"	"
3	"	PO	1.00	2.00	1.00	42	5.00	46.00	"	"	"
4	"	RI	"	"	"	41	55.00	12.10	"	"	"
5	"	PO	3.00	"	0	45	5.00	49.40	"	"	"
6	"	RI	"	"	"	"	55.00	11.20	"	"	"
7	"	PO	1.00	"	"	"	5.00	47.50	D	0.10	0.50
8	"	RI	"	"	"	44	55.00	10.00	"	"	"
9	"	PO	"	"	"	45	5.00	50.90	"	"	1.50
10	"	RI	"	"	"	44	55.00	10.00	"	"	"
11	"	PO	"	"	"	40	5.00	48.00	"	"	2.50
12	"	RI	"	"	"	39	55.00	12.25	"	"	"
13	"	PO	0.25	0.50	0.25	120	5.00	49.40	S	0	0
14	"	RI	"	"	"	116	55.00	12.20	"	"	"
15	"	PO	1.00	2.00	1.00	42	5.00	47.30	"	"	"
16	"	RI	"	"	"	"	55.00	12.45	"	"	"
17	"	PO	3.00	"	0	44	5.00	48.40	"	"	"
18	"	RI	"	"	"	43	55.00	9.90	"	"	"
19	"	PO	1.00	"	"	47	5.00	50.50	D	0.10	0.50
20	"	RI	"	"	"	44	55.00	9.90	"	"	"
21	"	PO	"	"	"	43	5.00	50.80	"	"	1.50
22	"	RI	"	"	"	44	55.00	9.50	"	"	"

[1] N = Nylon
R = Rubber
S = Static

[2] PO = pay-out
RI = reel-in

[3] D = Dynamic
S = Static

TABLE 1 (Continued)

INDEX OF TESTS

Test No.	Cable Matl.[1]	Dir.[2]	WINCH PARAMETERS Acc. ft/sec^2	Vel. ft/sec	Dec. ft/sec^2	Run time sec	Initial length ft	Final length ft	OSCILLATOR PARAMETERS Mode[3]	Amp. inch	Freq. Hz
23	N	PO	1.00	2.00	0	46	5.00	51.30	D	0.10	2.50
24	"	RI	"	"	"	46	55.00	10.20	"	"	"
25	R	PO	0.25	0.50	0.25	74	5.00	28.45	S	0	0
26	"	RI	"	"	"	117	30.00	-10.70	"	"	"
27	"	PO	1.00	2.00	1.00	32	5.00	28.20	"	"	"
28	"	RI	"	"	"	46	35.00	-6.00	"	"	"
29	"	PO	3.00	2.00	0	33	5.00	28.60	"	"	"
30	"	RI	"	"	"	42	30.00	3.00	"	"	"
31	"	PO	"	"	"	38	5.00	29.75	"	"	"
32	"	RI	"	"	"	28	30.00	7.50	"	"	"
33	"	PO	1.00	"	1.00	36	5.00	26.10	"	"	"
34	"	RI	"	"	"	32	30.00	9.70	"	"	"
35	"	PO	"	"	"	44	5.00	29.60	"	"	"
36	"	RI	"	"	"	43	30.00	9.40	"	"	"
37	"	PO	0.25	0.50	0.25	69	5.00	29.05	"	"	"
38	"	RI	"	"	"	87	30.00	2.50	"	"	"
39	"	PO	1.00	2.00	0	36	5.00	30.80	D	1.00	0.50
40	"	RI	"	"	"	33	30.00	5.70	"	"	"
41	"	PO	"	"	"	35	5.00	31.10	"	"	1.50
42	"	RI	"	"	"	30	30.00	5.80	"	"	"
43	"	PO	"	"	"	31	5.00	29.55	"	"	2.50
44	"	RI	"	"	"	35	30.00	6.20	"	"	"
45	"	PO	"	"	"	29	5.00	30.05	"	"	"
46	"	RI	"	"	"	31	30.00	7.70	"	"	"
47	"	PO	"	"	"	33	5.00	29.50	"	"	1.50
48	"	RI	"	"	"	29	30.00	6.40	"	"	"
49	"	PO	"	"	"	31	5.00	31.00	"	"	0.50
50	"	RI	"	"	"	30	30.00	7.60	"	"	"

TABLE 1 (Continued)

INDEX OF TESTS

Test No.	Cable Matl.[1]	Dir.[2]	Acc. ft/sec^2	Vel. ft/sec	Dec. ft/sec^2	Run time sec	Initial length ft	Final length ft	Mode[3]	Amp. inch	Freq. Hz
	WINCH PARAMETERS								OSCILLATOR PARAMETERS		
51	N	PO	1.00	2.00	0	47	5.00	49.20	D	1.00	0.50
52	"	RI	"	"	"	45	55.00	10.20	"	"	"
53	"	PO	"	"	"	51	5.00	51.30	"	"	1.50
54	"	RI	"	"	"	44	55.00	9.80	"	"	"
55	"	PO	"	"	"	"	5.00	49.60	"	"	"
56	"	RI	"	"	"	"	55.00	10.10	"	"	"
57	"	PO	"	"	"	49	5.00	51.45	"	"	0.50
58	"	RI	"	"	"	46	55.00	9.20	"	"	"
59	R	PO	"	"	"	37	5.00	29.20	"	"	0.25
60	"	RI	"	"	"	30	30.00	8.60	"	"	"
61	"	PO	"	"	"	34	5.00	29.00	"	"	0.10
62	"	RI	"	"	"	29	30.00	8.40	"	"	"
63	"	PO	"	"	"	30	5.00	29.30	"	"	2.67
64	"	RI	"	"	"	31	30.00	7.60	"	"	"
65	"	PO	"	"	"	29	5.00	30.40	"	"	1.00
66	"	RI	"	"	"	30	30.00	5.70	"	"	"
67	"	PO	"	"	"	29	5.00	29.75	"	"	"
68	"	RI	"	"	"	"	30.00	8.50	"	"	"
69	"	PO	"	"	"	32	5.00	30.60	"	"	2.67
70	"	RI	"	"	"	30	30.00	7.40	"	"	"
71	"	PO	"	"	"	34	5.00	32.10	"	"	0.10
72	"	RI	"	"	"	37	30.00	5.20	"	"	"
73	"	PO	"	"	"	38	5.00	26.25	"	"	0.25
74	"	RI	"	"	"	32	30.00	8.40	"	"	"
75	N	S	0	0	"	15	6.45	6.45	S	0	0
76	"	"	"	"	"	"	"	"	D	1.00	1.00
77	"	"	"	"	"	6	"	"	"	"	"

TABLE 1 (Concluded)

INDEX OF TESTS

Test No.	Cable Matl.[1]	Dir.[2]	Acc. ft/sec²	Vel. ft/sec	Dec. ft/sec²	Run time sec	Initial length ft	Final length ft	Mode[3]	Amp. inch	Freq. Hz
	WINCH PARAMETERS								OSCILLATOR PARAMETERS		
78	N	S	0	0	0	6	6.45	6.45	D	1.00	2.00
79	"	"	"	"	"	"	"	"	"	"	2.33
80	"	"	"	"	"	"	"	"	"	"	2.50
81	"	"	"	"	"	9	"	"	"	"	2.67
82	"	"	"	"	"	8	"	"	"	"	2.83
83	"	"	"	"	"	"	"	"	"	"	3.00
84	"	"	"	"	"	"	"	"	"	"	2.83
85	"	"	"	"	"	"	"	"	"	"	2.75
86	"	"	"	"	"	"	"	"	"	"	2.58
87	"	"	"	"	"	"	"	"	"	"	2.54
88	"	"	"	"	"	"	"	"	"	"	2.46
89	"	"	"	"	"	"	"	"	"	"	2.38
90	"	"	"	"	"	"	"	"	"	"	2.25
91	"	"	"	"	"	"	"	"	"	"	2.17
92	"	"	"	"	"	9	"	"	"	"	2.08
93	"	"	"	"	"	"	"	"	"	"	2.04
94	"	"	"	"	"	10	"	"	"	"	2.12
95	"	"	"	"	"	9	"	"	"	"	2.00
96	"	"	"	"	"	"	"	"	"	"	1.92
97	"	"	"	"	"	"	"	"	"	"	1.96

TABLE 2

TRANSDUCER LIST

Parameter	Transducer Type	Manufacturer	Range	Precision
1) Tension	Strain gage load cell	Tensitron, Inc. Harvard, Mass. S/N 27077	± 5 lb.	Combined linearity and hysteresis: ±0.5% full scale
2) Length	10 turn Helipot	Beckman Instruments Fullerton, Ca. Model A-R50k	50k ohm	Linearity: ± 0.25% full scale
3) Velocity	Tachometer	Sierracin-Magnedyne Carlsbad, Ca. P/N 435-05	± 3800 rpm	Sensitivity: 9.97V/K rpm Ripple: 0.12% full scale, pk to pk.
4) Phase Angle	Rotary Potentiometer	Bourns, Inc. Riverside, Ca. P/N 3445S-503	50 k ohm	Linearity: ± 0.2% full scale Dead band: 2 deg.

TABLE 3

ELASTIC CABLE PROPERTIES[1]

A. Manufacturer: Marsh Industries, Inc.
49680 Leona Dr., Mt. Clemens, MI 48043

B. Designation: Rubber Shock Mitigation Cord

C. Material: Solid rubber

D. Diameter: 0.159 inch (4.04 mm)

E. Weight per unit length: 0.0092 lb/ft (13.7 g/m)

F. Load deflection test results:

Load gram	Load lbs	Length L, inch	ΔL inch	L_1 inch
Pan	Pan	76.187		76.312
			+2.969	
50	0.11	79.156		79.281
			+3.406	
100	0.22	82.562		83.000
			+4.188	
150	0.33	86.750		87.060
			-2.938	
100	0.22	83.812		83.750
			-3.687	
50	0.11	80.125		80.000
			-3.313	
Pan	Pan	76.812		76.620[2]

Notes:

1) Dry cable in air

2) After two minutes, the length was 76.593 inch.

TABLE 2

TRANSDUCER LIST

Parameter	Transducer Type	Manufacturer	Range	Precision
1) Tension	Strain gage load cell	Tensitron, Inc. Harvard, Mass. S/N 27077	± 5 lb.	Combined linearity and hysteresis: ±0.5% full scale
2) Length	10 turn Helipot	Beckman Instruments Fullerton, Ca. Model A-R50k	50k ohm	Linearity: ± 0.25% full scale
3) Velocity	Tachometer	Sierracin-Magnedyne Carlsbad, Ca. P/N 435-05	± 3800 rpm	Sensitivity: 9.97V/K rpm Ripple: 0.12% full scale, pk to pk.
4) Phase Angle	Rotary Potentiometer	Bourns, Inc. Riverside, Ca. P/N 3445S-503	50 k ohm	Linearity: ± 0.2% full scale Dead band: 2 deg.

TABLE 4

INELASTIC CABLE PROPERTIES

A. Manufacturer: Cortland Line Company
67 East Court St., Cortland, NY 13045

B. Designation: 100 lb test, braided

C. Material: Nylon

D. Diameter (dry): 0.059 in (1.50 mm)

E. Weight per unit length (dry): 0.000792 lb/ft (1.18 g/m)

F. Load-deflection test results:

Test No. 1

Load w, grams	lbs	Length L, inch	ΔL inch	L_1 inch
PAN	PAN	75.80	0.16	75.81
50	0.11	75.96	0.14	76.08
100	0.22	76.10	0.10	76.13
150	0.33	76.20	0.09	76.21
200	0.44	76.29	0.05	76.3
250	0.55	76.34	0.06	76.34
300	0.66	76.40	0.05	76.40
350	0.77	76.45	0.03	76.45
400	0.88	76.48	0.02	76.48
450	0.99	76.50	-0.06	76.50
400	0.88	76.44	-0.07	76.43
350	0.77	76.37	-0.08	76.35
300	0.66	76.29	-0.09	76.28
250	0.55	76.20	-0.07	76.19
200	0.44	76.13	-0.09	76.12

((

TABLE 4 (Continued)

Test No. 1 - cont.

Load w,		Length L, inch	Δ L inch	L_1 inch
150	0.33	76.04		76.02
			-0.05	
100	0.22	75.99		75.94
			-0.11	
50	0.11	75.88		75.87
			-0.08	
PAN	PAN	75.80		75.78

Test No. 2

(re-wet line 30 minutes in water)

Load w, grams	lbs.	Length L, inch	Δ L inch	L_1 inch
PAN	PAN	75.78		75.79
			0.24	
50	0.11	76.02		76.04
			0.12	
100	0.22	76.14		76.06
			0.09	
150	0.33	76.23		76.25
			0.07	
200	0.44	76.30		76.33
			0.08	
250	0.55	76.38		76.40
			0.10	
300	0.66	76.48		76.49
			0.04	
350	0.77	76.52		76.50
			0.01	
400	0.88	76.53		76.50
			0.01	
450	0.99	76.54		76.51
			-0.07	
400	0.88	76.47		76.38
			-0.08	
350	0.77	76.39		76.35
			-0.06	
300	0.66	76.33		76.30
			-0.10	
250	0.55	76.23		76.20
			-0.06	
200	0.44	76.17		76.14
			-0.13	

TABLE 4 (Continued)

Test No. 2 - cont.

Load w,		Length L, inch	Δ L inch	L_1 inch
150	0.33	76.04		76.03
			-0.06	
100	0.22	75.98		75.96
			-0.13	
50	0.11	75.85		75.83
			-0.09	
PAN	PAN	75.76		75.73

Test No. 3

(re-wet line 30 minutes in water)

Load w, grams	lbs.	Length L, inch	Δ L inch	L_1 inch
PAN	PAN	75.70		75.71
			0.24	
50	0.11	75.94		75.98
			0.14	
100	0.22	76.08		76.01
			0.10	
150	0.33	76.18		76.11
			0.11	
200	0.44	76.29		76.30
			0.05	
250	0.55	76.34		76.36
			0.07	
300	0.66	76.41		76.42
			0.06	
350	0.77	76.47		76.45
			0.03	
400	0.88	76.50		76.47
			0.0	
450	0.99	76.50		76.47
			-0.08	
400	0.88	76.42		76.40
			-0.08	
350	0.77	76.34		76.32
			-0.07	
300	0.66	76.27		76.25
			-0.09	
250	0.55	76.18		76.15
			-0.09	
200	0.44	76.09		76.08
			-0.09	
150	0.33	76.00		75.90
			-0.07	

TABLE 4 (Concluded)

Test No. 3 - cont.

Load w,		Length L, inch	Δ L inch	L_1 inch	
100	0.22	75.93		75.90	
			-0.12		
50	0.11	75.81		75.79	
			-0.07		
PAN	PAN	75.74		75.72	
PAN	PAN			75.13	(30 min.)

TABLE 5

EFFECT OF WATER IMMERSION
ON INELASTIC CABLE LENGTH

I. Long duration creep under tension when wet:

Immersion time, hrs.	Length m	Remarks
0.0	9.000	Dry length measured prior to immersion ± 0.001 m.
23.5	9.100	Cable held in tension with model anchor when in water
47.5	9.100	
71.5	9.100	After 5 min. in air, chord contracted to 9.095 m.
95.5	9.100	The chord exhibited the short time drying contractions listed in the task below
167.0	10.080	
213.0	9.080	

II. Short duration contraction when drying:

Time in air min.	Length m
0	9.100
5	9.095
10	9.088
15	9.075

TABLE 6

EXPERIMENTAL DATA

VARIABLE LENGTH CABLE SYSTEMS DYNAMICS

TEST NO. 52

WINCH PARAMETERS
CABLE MATERIAL .... NYLON
DIRECTION .... PAY-OUT
ACCELERATION, FPS2 ... 0.25
VELOCITY, FPS 0.50
DECELERATION, FPS2 ... 0.25
RUN TIME, SEC 117.00
INITIAL LENGTH, FT ... 5.00
FINAL LENGTH, FT 49.70

OSCILLATOR PARAMETERS
MODE .... STATIC
AMPLITUDE, INCH ... 0.0
FREQUENCY, HZ 0.0

DATA PARAMETERS
ID = 60
NREC = 117
NCHN = 6
NWRD = 6000
KV = 1.170E-01
KA = 1.120E-01

			ENGLISH UNITS				METRIC UNITS			
RCDR TIME	RUN TIME	OSCL. ANGLE	TENSION	LENGTH	VELOCITY	ACCEL.	TENSION	LENGTH	VELOCITY	ACCEL.
SEC	SEC	DEG	LBS	FT	FT/SEC	FT/SEC/SEC	GRAM	CM	CM/SEC	CM/SEC/SEC
0.0	0.0	1.6	1.002E 00	7.19	-3.737E-03	-1.449E-03	4.545E 02	2.191E 02	-1.139E-01	-4.415E-02
0.100	0.0	1.6	1.001E 00	7.19	-3.915E-03	-1.459E-03	4.541E 02	2.191E 02	-1.193E-01	-4.448E-02
0.200	0.0	1.5	1.002E 00	7.20	-3.817E-03	-1.611E-03	4.547E 02	2.190E 02	-1.163E-01	-4.911E-02
0.300	0.0	1.5	1.003E 00	7.17	-4.040E-03	-1.528E-03	4.550E 02	2.187E 02	-1.232E-01	-4.657E-02
0.400	0.0	1.5	1.002E 00	7.17	-3.830E-03	-1.624E-03	4.547E 02	2.185E 02	-1.167E-01	-4.951E-02
0.500	0.0	1.7	9.985E-01	7.18	-4.119E-03	-1.454E-03	4.529E 02	2.187E 02	-1.255E-01	-4.432E-02
0.600	0.0	1.7	9.988E-01	7.18	-3.735E-03	-1.356E-03	4.530E 02	2.187E 02	-1.138E-01	-4.132E-02
0.700	0.0	1.6	9.991E-01	7.18	-3.860E-03	-1.554E-03	4.532E 02	2.188E 02	-1.176E-01	-4.738E-02
0.800	0.0	1.7	9.994E-01	7.17	-4.061E-03	-1.304E-03	4.533E 02	2.184E 02	-1.238E-01	-3.973E-02
0.900	0.0	1.7	9.991E-01	7.17	-3.563E-03	-1.580E-03	4.532E 02	2.185E 02	-1.086E-01	-4.815E-02
1.000	0.0	1.7	9.991E-01	7.17	-3.582E-03	-1.487E-03	4.532E 02	2.186E 02	-1.092E-01	-4.534E-02
1.100	0.0	1.7	9.992E-01	7.17	-3.712E-03	-1.584E-03	4.532E 02	2.184E 02	-1.131E-01	-4.828E-02
1.200	0.0	1.7	9.991E-01	7.17	-3.659E-03	-1.443E-03	4.532E 02	2.187E 02	-1.115E-01	-4.398E-02
1.300	0.0	1.7	9.987E-01	7.18	-3.571E-03	-1.537E-03	4.530E 02	2.188E 02	-1.089E-01	-4.684E-02
1.400	0.0	1.8	9.990E-01	7.18	-3.273E-03	-1.231E-03	4.531E 02	2.190E 02	-9.975E-02	-3.753E-02
1.500	0.0	1.7	9.993E-01	7.18	-3.579E-03	-1.369E-03	4.533E 02	2.188E 02	-1.091E-01	-4.171E-02
1.600	0.0	1.7	9.980E-01	7.19	-3.658E-03	-1.351E-03	4.527E 02	2.192E 02	-1.115E-01	-4.117E-02
1.700	0.0	1.7	9.987E-01	7.19	-3.577E-03	-1.381E-03	4.530E 02	2.192E 02	-1.090E-01	-4.209E-02
1.800	0.0	1.7	9.983E-01	7.20	-3.567E-03	-1.288E-03	4.528E 02	2.193E 02	-1.087E-01	-3.925E-02
1.900	0.0	1.6	9.995E-01	7.18	-3.612E-03	-1.463E-03	4.534E 02	2.189E 02	-1.101E-01	-4.459E-02
2.000	0.0	1.6	9.994E-01	7.17	-3.628E-03	-1.486E-03	4.533E 02	2.187E 02	-1.106E-01	-4.530E-02
2.100	0.0	1.7	9.994E-01	7.18	-3.925E-03	-1.503E-03	4.533E 02	2.187E 02	-1.196E-01	-4.582E-02
2.200	0.0	1.6	9.996E-01	7.19	-3.620E-03	-1.420E-03	4.534E 02	2.191E 02	-1.103E-01	-4.328E-02
2.300	0.0	1.7	9.990E-01	7.18	-3.754E-03	-1.415E-03	4.532E 02	2.190E 02	-1.144E-01	-4.313E-02
2.400	0.0	1.7	9.987E-01	7.18	-3.709E-03	-1.425E-03	4.530E 02	2.189E 02	-1.131E-01	-4.344E-02
2.500	0.0	1.7	9.985E-01	7.18	-3.942E-03	-1.405E-03	4.529E 02	2.187E 02	-1.201E-01	-4.282E-02
2.600	0.0	1.7	9.990E-01	7.17	-3.615E-03	-1.515E-03	4.532E 02	2.185E 02	-1.102E-01	-4.617E-02
2.700	0.0	1.7	9.997E-01	7.18	-3.406E-03	-1.511E-03	4.534E 02	2.188E 02	-1.038E-01	-4.605E-02
2.800	0.0	1.6	9.992E-01	7.18	-3.626E-03	-1.611E-03	4.532E 02	2.189E 02	-1.105E-01	-4.911E-02
2.900	0.0	1.8	9.986E-01	7.19	-3.587E-03	-1.550E-03	4.529E 02	2.191E 02	-1.093E-01	-4.726E-02
3.000	0.0	1.7	9.981E-01	7.19	-3.498E-03	-1.345E-03	4.527E 02	2.192E 02	-1.066E-01	-4.101E-02
3.100	0.0	1.8	9.975E-01	7.18	-3.343E-03	-1.440E-03	4.525E 02	2.190E 02	-1.019E-01	-4.390E-02
3.200	0.0	1.7	9.983E-01	7.20	-3.276E-03	-1.292E-03	4.528E 02	2.195E 02	-9.986E-02	-3.938E-02
3.300	0.0	1.8	9.985E-01	7.20	-3.606E-03	-1.409E-03	4.529E 02	2.195E 02	-1.099E-01	-4.294E-02

TABLE 6 (cont'd.)

EXPERIMENTAL DATA

VARIABLE LENGTH CABLE SYSTEMS DYNAMICS

RCDR TIME	RUN TIME	OSCL. ANGLE	ENGLISH UNITS TENSION	ENGLISH UNITS LENGTH	ENGLISH UNITS VELOCITY	ENGLISH UNITS ACCEL.	METRIC UNITS TENSION	METRIC UNITS LENGTH	METRIC UNITS VELOCITY	METRIC UNITS ACCEL.
SEC	SEC	DEG	LBS	FT	FT/SEC	FT/SEC/SEC	GRAM	CM	CM/SEC	CM/SEC/SEC
3.400	0.0	1.7	9.983E-01	7.21	-3.655E-03	-1.206E-03	4.528E 02	2.197E 02	-1.114E-01	-3.675E-02
3.500	0.0	1.8	9.982E-01	7.20	-3.676E-03	-1.306E-03	4.528E 02	2.194E 02	-1.120E-01	-3.982E-02
3.600	0.0	1.8	9.985E-01	7.18	-3.434E-03	-1.531E-03	4.529E 02	2.188E 02	-1.047E-01	-4.665E-02
3.700	0.0	1.7	1.000E 00	7.19	-3.427E-03	-1.466E-03	4.536E 02	2.190E 02	-1.045E-01	-4.467E-02
3.800	0.0	1.7	9.991E-01	7.20	-3.546E-03	-1.470E-03	4.532E 02	2.194E 02	-1.081E-01	-4.480E-02
3.900	0.0	1.7	9.980E-01	7.19	-3.326E-03	-1.429E-03	4.527E 02	2.190E 02	-1.014E-01	-4.355E-02
4.000	0.0	1.7	1.000E 00	7.18	-3.174E-03	-1.505E-03	4.538E 02	2.190E 02	-9.673E-02	-4.586E-02
4.100	0.0	1.7	1.000E 00	7.17	-3.165E-03	-1.550E-03	4.536E 02	2.185E 02	-9.647E-02	-4.724E-02
4.200	0.0	1.8	9.999E-01	7.18	-3.140E-03	-1.460E-03	4.535E 02	2.187E 02	-9.571E-02	-4.451E-02
4.300	0.0	1.7	9.997E-01	7.18	-3.460E-03	-1.479E-03	4.535E 02	2.187E 02	-1.055E-01	-4.509E-02
4.400	0.0	1.7	9.988E-01	7.18	-3.084E-03	-1.421E-03	4.530E 02	2.187E 02	-9.399E-02	-4.330E-02
4.500	0.0	1.8	9.981E-01	7.19	-3.245E-03	-1.390E-03	4.528E 02	2.192E 02	-9.891E-02	-4.238E-02
4.600	0.0	1.8	9.980E-01	7.20	-3.105E-03	-1.314E-03	4.527E 02	2.194E 02	-9.464E-02	-4.005E-02
4.700	0.0	1.9	9.981E-01	7.19	-3.028E-03	-1.317E-03	4.527E 02	2.192E 02	-9.229E-02	-4.013E-02
4.800	0.0	1.8	9.991E-01	7.20	-2.959E-03	-1.299E-03	4.532E 02	2.195E 02	-9.018E-02	-3.959E-02
4.900	0.0	1.8	9.983E-01	7.21	-2.917E-03	-1.367E-03	4.528E 02	2.196E 02	-8.891E-02	-4.165E-02
5.000	0.0	1.7	9.981E-01	7.21	-3.456E-03	-1.311E-03	4.527E 02	2.197E 02	-1.053E-01	-3.996E-02
5.100	0.0	1.8	9.988E-01	7.20	-3.144E-03	-1.248E-03	4.530E 02	2.193E 02	-9.581E-02	-3.803E-02
5.200	0.0	1.7	9.984E-01	7.19	-3.162E-03	-1.494E-03	4.529E 02	2.190E 02	-9.638E-02	-4.553E-02
5.300	0.0	1.7	9.988E-01	7.19	-3.217E-03	-1.401E-03	4.531E 02	2.191E 02	-9.806E-02	-4.265E-02
5.400	0.0	1.7	9.988E-01	7.19	-3.343E-03	-1.477E-03	4.531E 02	2.192E 02	-1.019E-01	-4.501E-02
5.500	0.0	1.6	9.996E-01	7.19	-3.153E-03	-1.240E-03	4.534E 02	2.193E 02	-9.610E-02	-3.780E-02
5.600	0.0	1.7	9.990E-01	7.18	-3.219E-03	-1.360E-03	4.531E 02	2.189E 02	-9.812E-02	-4.144E-02
5.700	0.0	1.8	9.982E-01	7.18	-3.114E-03	-1.525E-03	4.528E 02	2.190E 02	-9.492E-02	-4.648E-02
5.800	0.0	1.8	9.984E-01	7.18	-3.131E-03	-1.390E-03	4.529E 02	2.190E 02	-9.542E-02	-4.236E-02
5.900	0.0	1.8	9.989E-01	7.19	-3.266E-03	-1.472E-03	4.531E 02	2.190E 02	-9.956E-02	-4.486E-02
6.000	0.0	1.8	9.978E-01	7.19	-3.341E-03	-1.531E-03	4.526E 02	2.193E 02	-1.018E-01	-4.665E-02
6.100	0.0	1.8	9.974E-01	7.20	-3.042E-03	-1.185E-03	4.524E 02	2.194E 02	-9.272E-02	-3.613E-02
6.200	0.0	1.8	9.978E-01	7.21	-3.175E-03	-1.291E-03	4.526E 02	2.197E 02	-9.677E-02	-3.934E-02
6.300	0.0	1.9	9.977E-01	7.21	-2.945E-03	-1.207E-03	4.526E 02	2.197E 02	-8.976E-02	-3.678E-02
6.400	0.0	1.9	9.976E-01	7.21	-3.183E-03	-1.051E-03	4.525E 02	2.197E 02	-9.701E-02	-3.202E-02
6.500	0.0	1.8	9.978E-01	7.21	-2.911E-03	-1.213E-03	4.526E 02	2.198E 02	-8.874E-02	-3.696E-02
6.600	0.0	1.7	9.982E-01	7.21	-3.206E-03	-1.151E-03	4.528E 02	2.199E 02	-9.773E-02	-3.509E-02
6.700	0.0	1.8	9.981E-01	7.20	-2.931E-03	-1.258E-03	4.527E 02	2.195E 02	-8.933E-02	-3.836E-02
6.800	0.0	1.8	9.979E-01	7.20	-3.146E-03	-1.186E-03	4.527E 02	2.195E 02	-9.590E-02	-3.615E-02
6.900	0.0	1.9	9.976E-01	7.20	-3.184E-03	-1.414E-03	4.525E 02	2.195E 02	-9.703E-02	-4.309E-02
7.000	0.0	1.7	9.986E-01	7.20	-2.932E-03	-1.310E-03	4.530E 02	2.194E 02	-8.937E-02	-3.992E-02
7.100	0.0	1.7	9.989E-01	7.20	-3.066E-03	-1.316E-03	4.531E 02	2.196E 02	-9.344E-02	-4.011E-02
7.200	0.0	1.7	9.977E-01	7.20	-3.194E-03	-1.261E-03	4.526E 02	2.195E 02	-9.736E-02	-3.842E-02
7.300	0.0	1.9	9.970E-01	7.19	-2.956E-03	-1.483E-03	4.522E 02	2.191E 02	-9.011E-02	-4.519E-02
7.400	0.0	1.7	9.988E-01	7.19	-2.975E-03	-1.193E-03	4.530E 02	2.191E 02	-9.068E-02	-3.636E-02
7.500	0.0	1.8	9.992E-01	7.19	-3.059E-03	-1.483E-03	4.532E 02	2.193E 02	-9.325E-02	-4.519E-02
7.600	0.0	1.8	9.982E-01	7.20	-3.179E-03	-1.356E-03	4.528E 02	2.194E 02	-9.688E-02	-4.132E-02
7.700	0.0	1.7	9.976E-01	7.20	-2.989E-03	-1.343E-03	4.525E 02	2.196E 02	-9.111E-02	-4.092E-02
7.800	0.0	1.8	9.973E-01	7.21	-3.199E-03	-1.265E-03	4.524E 02	2.197E 02	-9.751E-02	-3.857E-02
7.900	0.0	1.8	9.973E-01	7.21	-2.992E-03	-1.184E-03	4.524E 02	2.198E 02	-9.120E-02	-3.609E-02

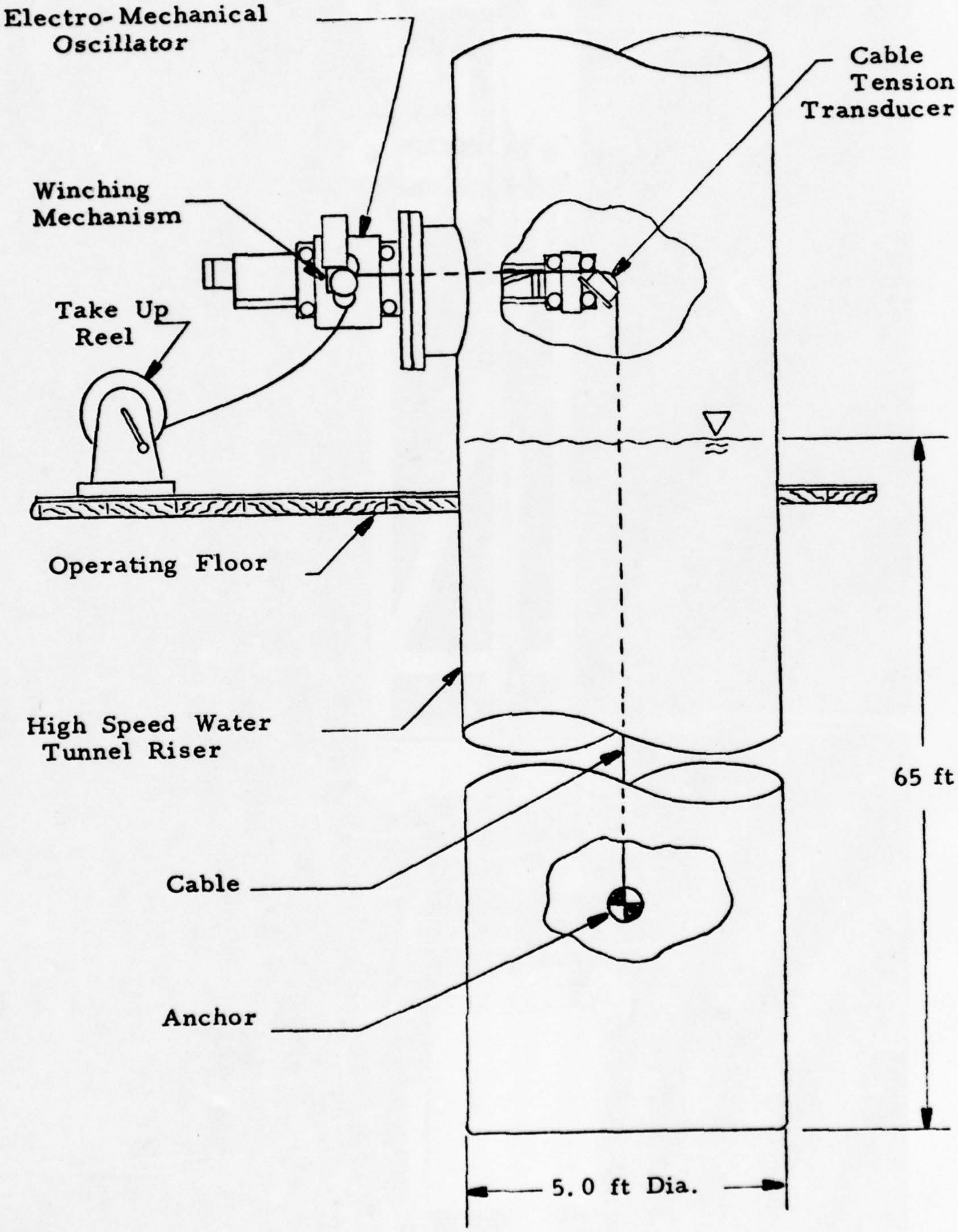

Figure 1. Experimental Arrangement

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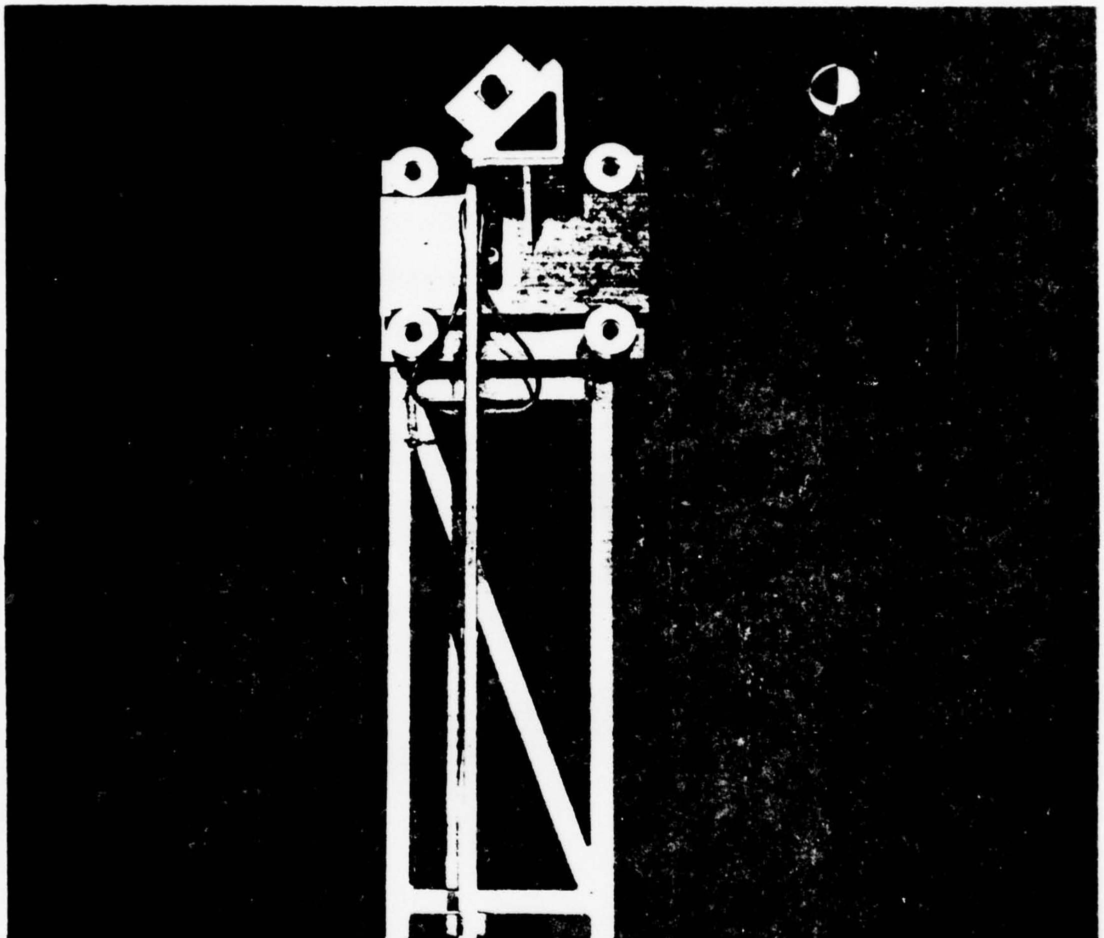

Figure 2. Electro-mechanical oscillator; winch side.

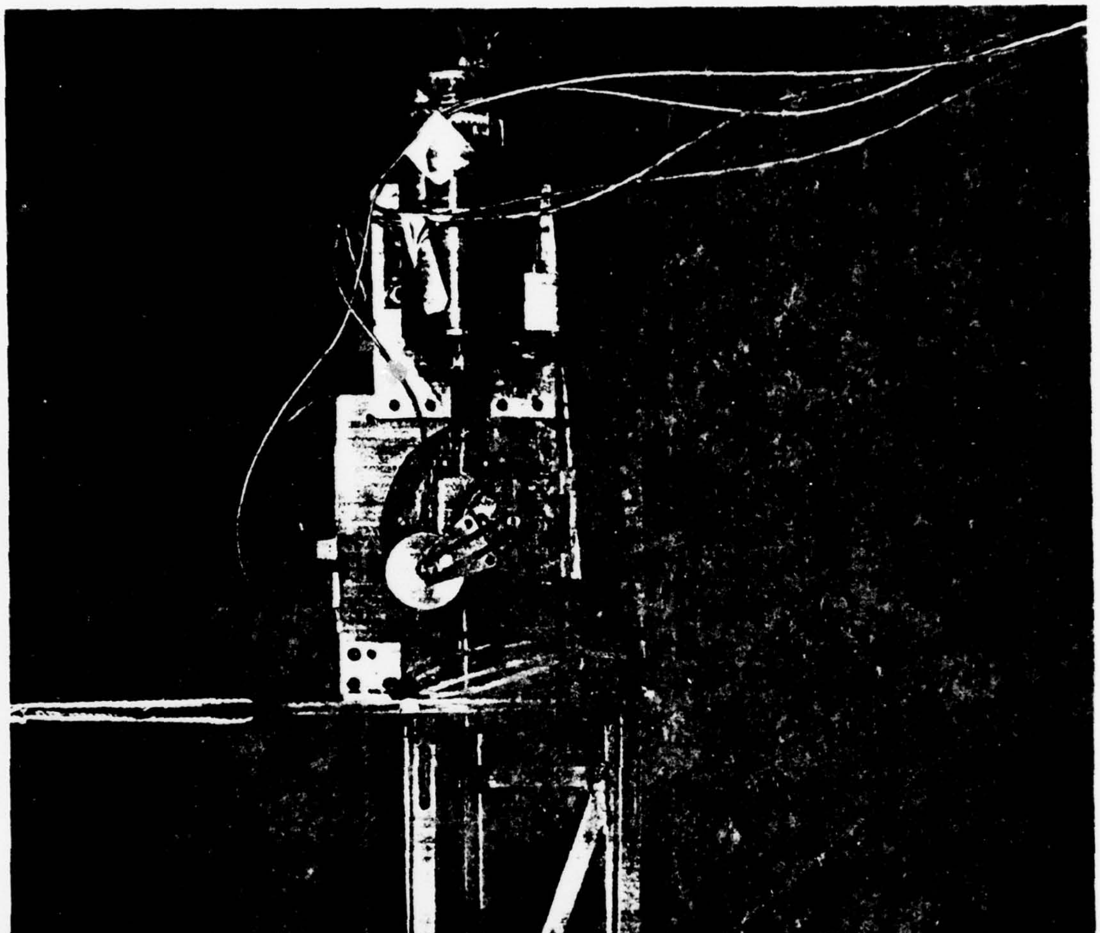

Figure 3. Electro-mechanical oscillator; drive side.

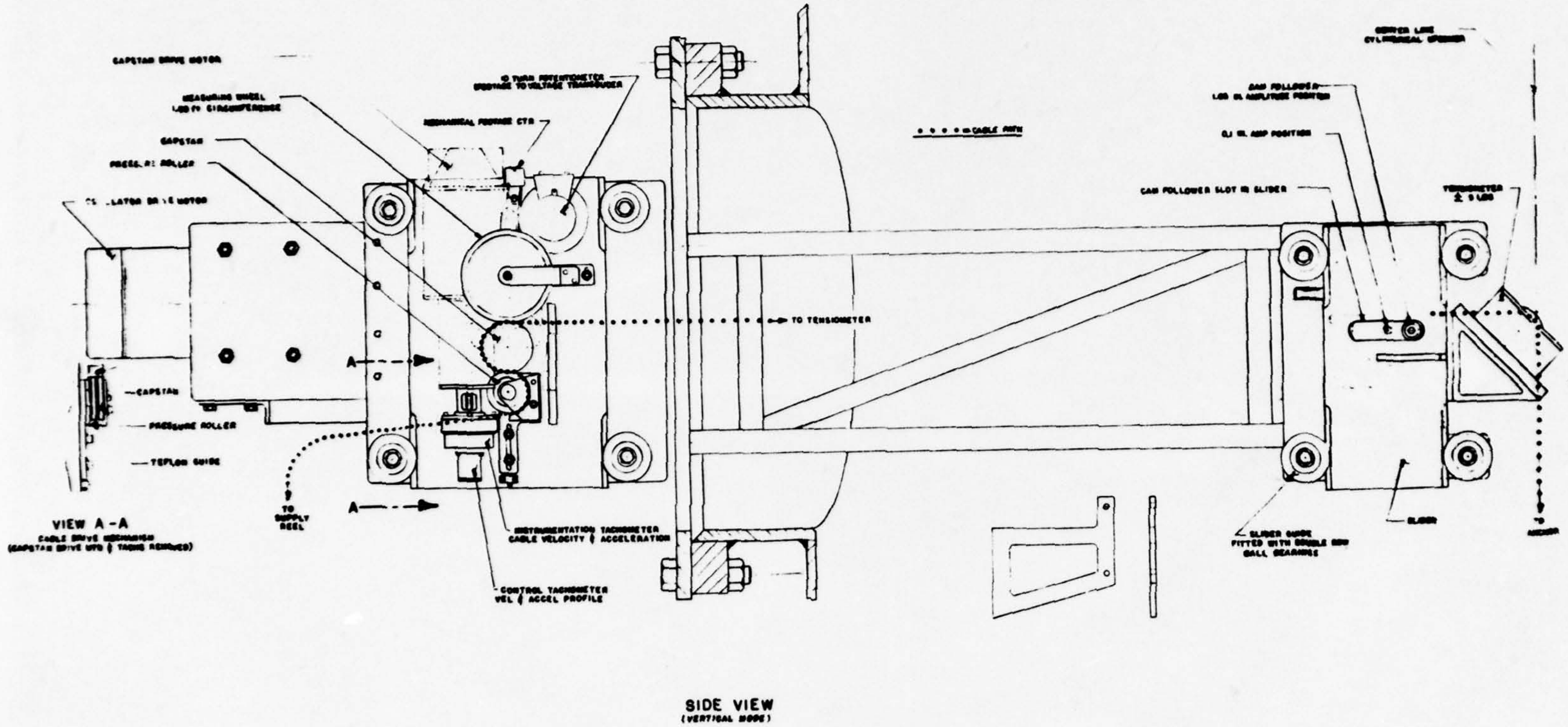

Figure 4. Arrangement drawing; electro-mechanical oscillator, winch side.

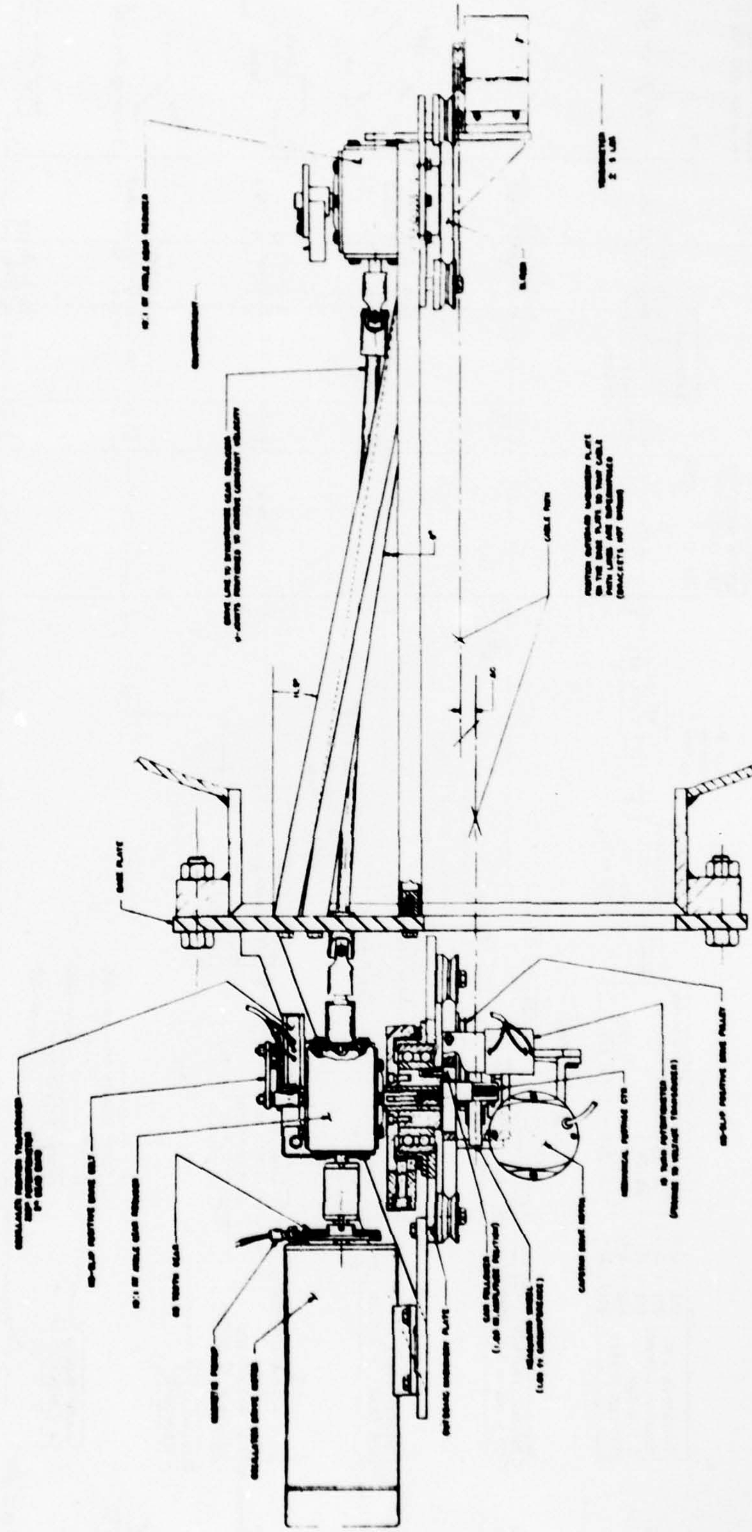

Figure 5. Arrangement drawing; electro-mechanical oscillator, top view.

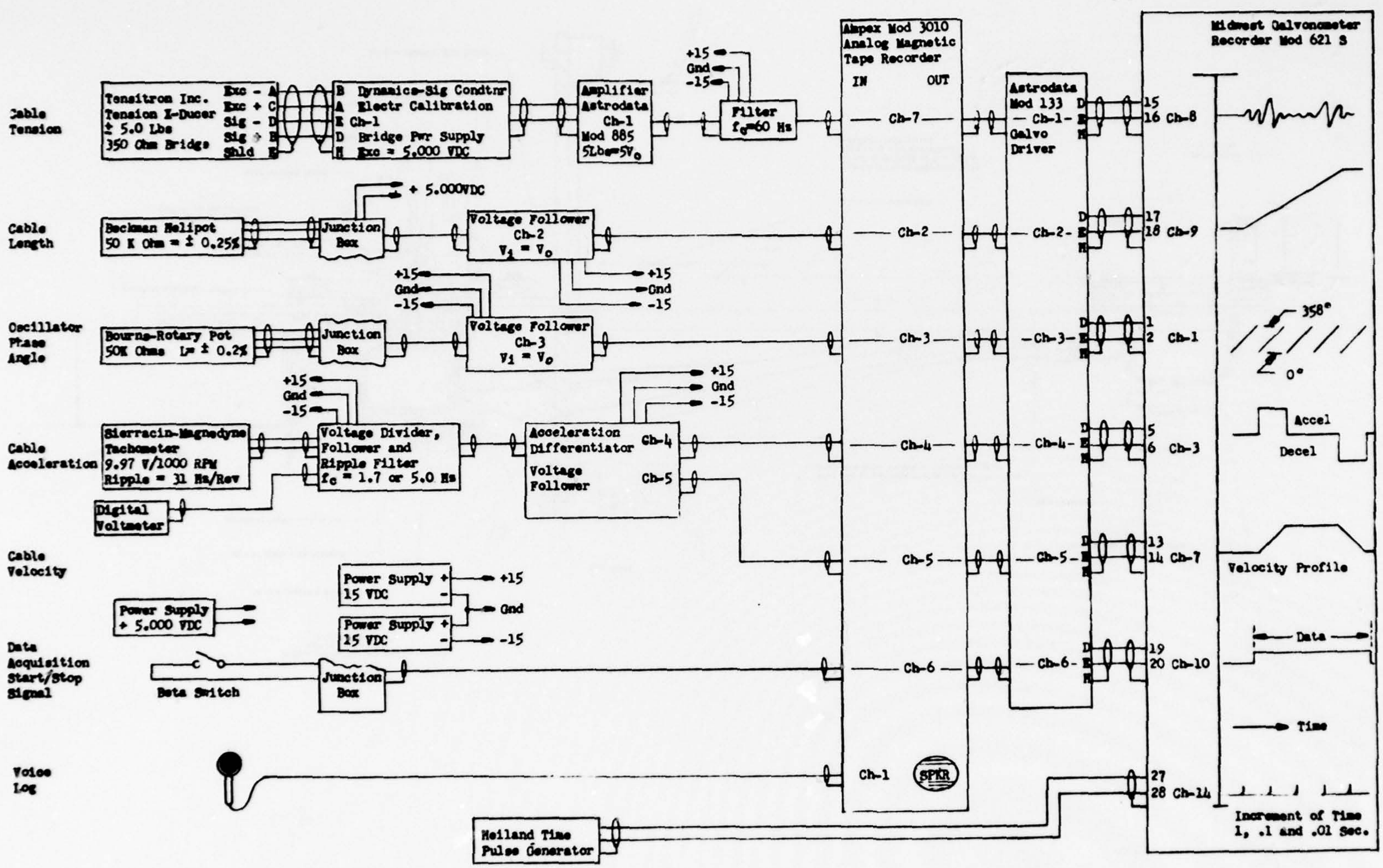

Figure 6. Instrumentation schematic.

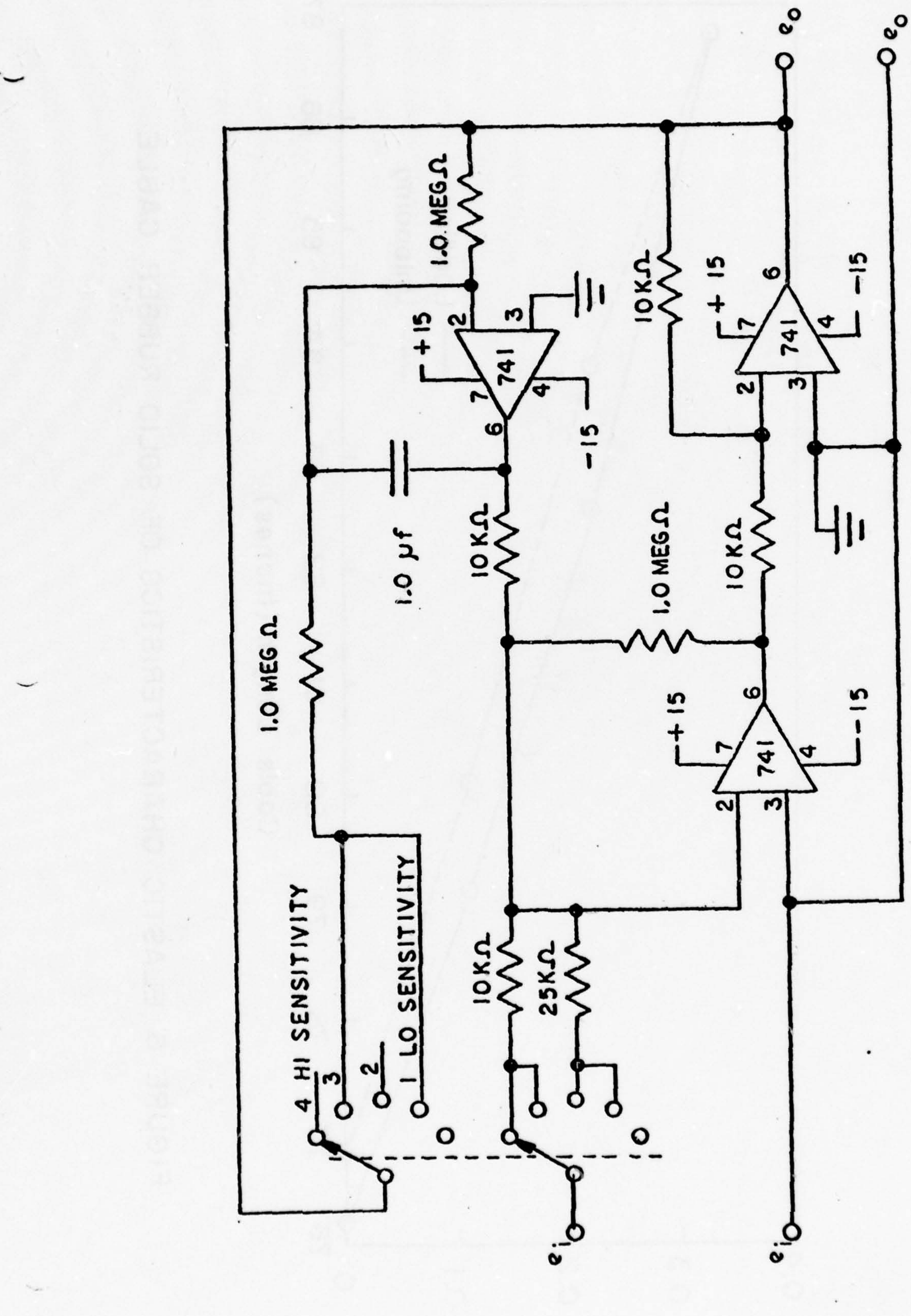

Figure 7. Differentiator Circuit Diagram

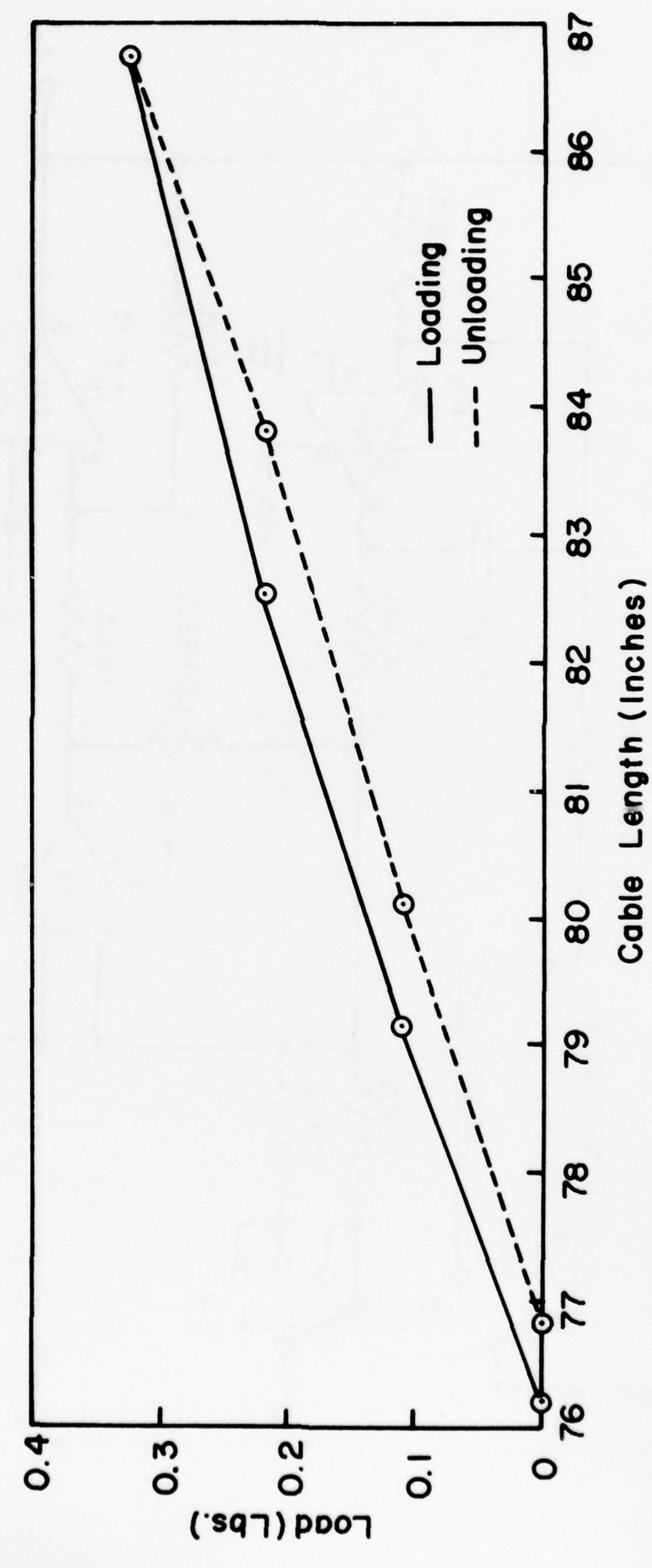

FIGURE 8. ELASTIC CHARACTERISTICS OF SOLID RUBBER CABLE

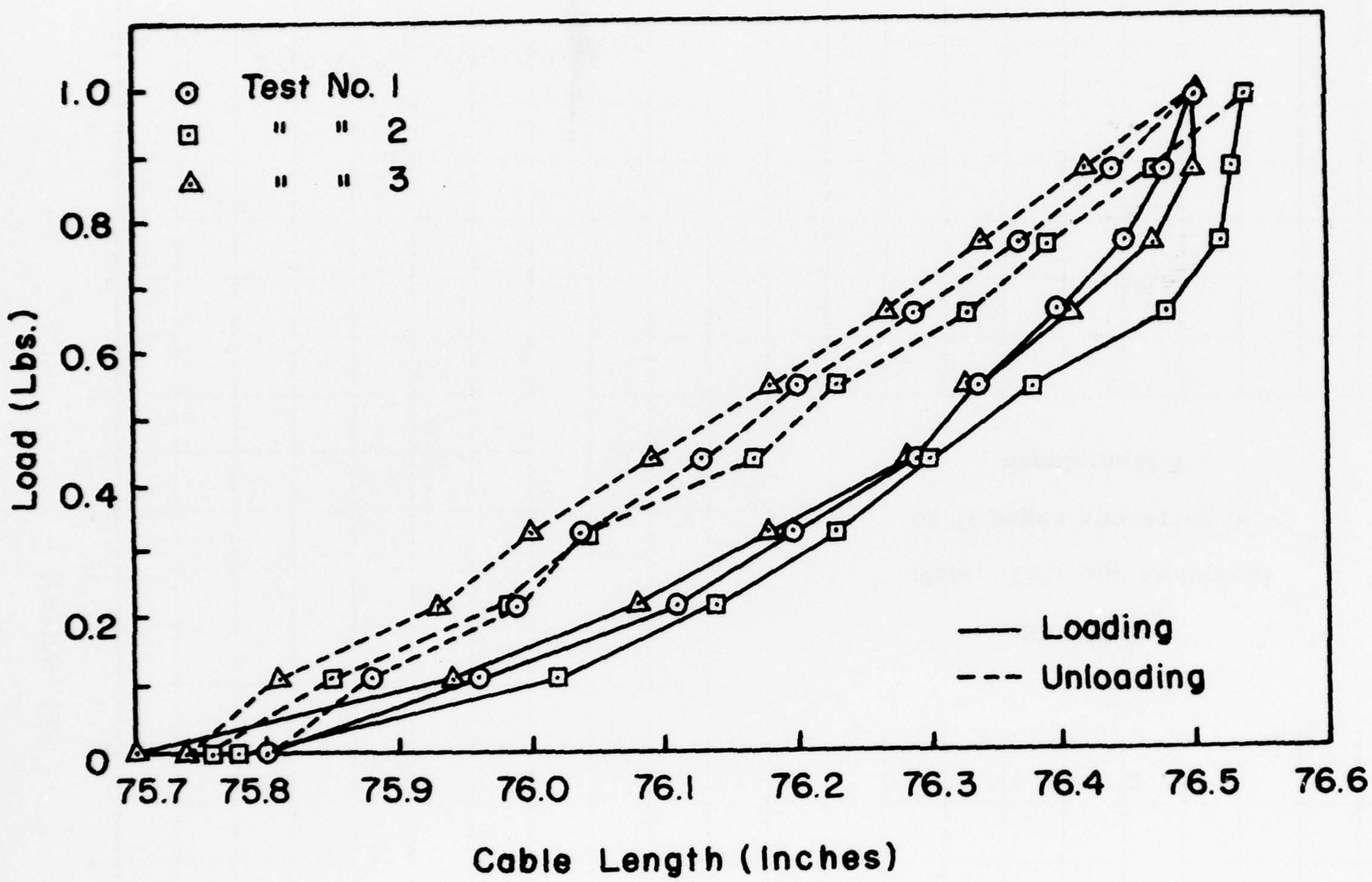

FIGURE 9. ELASTIC CHARACTERISTICS OF NYLON CABLE

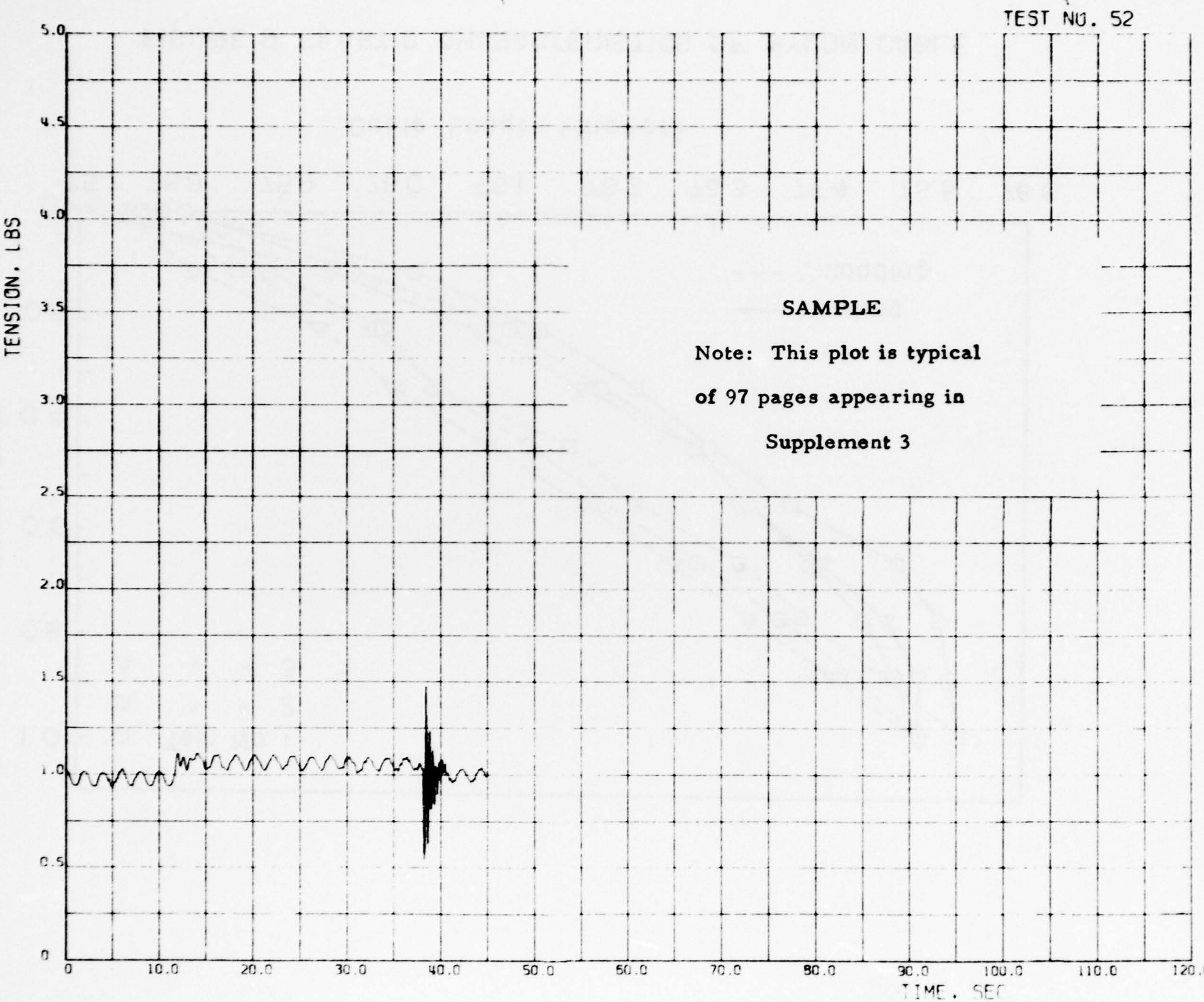

Figure 10. Tension vs. Time ; Test No. 52

APPENDIX I

DATA TAPE FORMAT AND PROGRAM

DATA TAPE FORMAT AND PROGRAM

The Fortran program VLCD1129, which follows, reads a tape (CBL 21 or CBL 22) and data cards with test parameters, processes the data, prints the table "Experimental Data" and plots tension vs. time for each test. The program requires two subroutines which are included and calls several CIT routines for the IBM 370. The program includes constants which convert ADC words on the tape to voltages and voltages to English units and English units to metric units.

The program proceeds test by test. To begin a test, lines are counted so that a heading can be put at the top of each page and a data card is read for:

IREP	GALCIT HSWT report number, which is 1129
ITEST	Test number
ICM	Cable material code Nylon = 1 Rubber = 2
IDIR	Direction code Pay-out = 1 Reel-in = 2 Siene = static = 3
ACC	Acceleration in ft/sec^2
VEL	Velocity in ft/sec
DEC	Deceleration in ft/sec^2
NREC	Number of records or run time in sec as each record contains 1 second of data in real time
RIL	Initial length in ft.
FL	Final length in ft.

MODE	Mode code Dynamic = 1 Static = 2
AMP	Amplitude in inches
FREQ	Frequency in Hz
ID	Identification number
RKV	KV, velocity calibration factor
RKA	KA, acceleration calibration factor

The value of IREP is tested to determine if this card has values for DELTAT, NINT, and NAVE. If it has, CIT routine XBACK is called to reread the data card with

DELTAT	$\Delta T \geq .005$
NINT	$1/\Delta T$
NAVE	$1000 * \Delta T$

Then the next data card is read with the identification and parameters for a test.

The first record from a file (a file corresponds to a test) on magnetic tape is read using CIT routine - 370 READRC (IDATA, NB), where INTEGER * 2 IDATA (6000) is the array where the retrieved record will be stored and NB is the length of the record read in bytes. The tape was created on a Hewlett Packard Model 7970E magnetic tape with 1 record = 6000 words. In the IBM system one of these words equals 2 bytes and one record contains 12000 bytes. This first record on a file contains:

IDATA(1)	=	ID	Identification number
IDATA(2)	=	NREC	Number of records on run time in sec.
IDATA(3)	=	NCHN	Number of channels = 6
IDATA(4)	=	NWRD	Number of words in a record = 6000

Only the first five channels are used. On all but the first record on a file, the first channel corresponds to time, the second to length, the third to oscillating angle, the forth to acceleration, and the fifth to velocity.

Each record subsequent to the first is read and the data is averaged according to the value of ΔT which has been selected. This averaged data is converted from ADC words into voltages and then into English and metric units. The data is printed in a table. The next record is read until the end of file is reached. Then a plot of tension vs. time is produced on the Calcomp plotter using a CIT routine - 370 XYPLØT.

This program uses two subroutines, HDG1 and GD1129, which are included with the main Fortran program. The first, subroutine HDG1, puts a heading on each page after the first for each test of "Experimental Data." Plain white paper was used for the plots. Subroutine GD1129 draws the axes lines, lines to form a grid, prints the axes titles and scale numbers. Several CIT routines - 370 were used in this subroutine.

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```
C     VLCD1129
C     2/9/78
C     3/3/78
C     3/8/78
C
C
C     THIS IS THE FINAL VERSION.
C     CHANGES HAVE BEEN MADE IN THE CONSTANTS AND IN THE EQUATIONS
C     TO CHANGE VOLTAGES INTO ENGLISH UNITS.
C
C
C     GALCIT REPORT HSWT-1129
C     W.O. 97683
C     THIS PROGRAM IS TO READ A TAPE ( CBL21 OR CBL22 ),
C     PROCESS THE DATA, AND PRINT
C     "EXPERIMENTAL DATA"
C     FOR PROPERLY DEFINED VALUES OF DELTA T
C     WITH DELTA T GREATER THAN OR EQUAL TO .005
C     PLOT TENSION, LBS VS TIME, SEC
C     THIS PROGRAM REQUIRES SUBROUTINE HOG1 AND SUBROUTINE GD1129
      COMMON/  SHOG1/ITEST,ICX,IDIR,ACC,VEL,DEC,RT,RIL,FL,MODE,AMP,FREQ,
     1IO,NREC,RKV,RKA
      INTEGER*2 IDATA(6000)
      REAL JDATA(1000)
      DIMENSION IC(5),VC(5)
      DIMENSION TPLOT(24000),TIME(24000)
      DIMENSION DOC(3)
      DATA DOC/0.,0.,0./
      DATA NCHN,NWRD / 6,6000/
      DATA PI/3.14159/
C
C     CONSTANT TO CONVERT ADC WORDS INTO VOLTAGES
C
      R1=1./3276.8
C
C     CONSTANTS TO BE USED IN CONVERTING VOLTAGES INTO ENGLISH UNITS
C
C     DATA RKT,RKX,RKO / -1.2333,15.718,89.493/              3/8/78
      DATA RKT,RKX,RKO / -1.2187,15.718,89.493/
C
C     CONSTANTS TO CONVERT ENGLISH UNITS INTO METRIC UNITS
C
      DATA PLBG,FTCM / 453.5924,30.48/
      WRITE (2,200)
  200 FORMAT (1H1,//,10X,'GALCIT REPORT HSWT-1129'//
     1      10X,'INPUT FOR VLCD1129'///)
C
C     TO BEGIN A TEST
C     TO COUNT LINES ON A PAGE
C
   10 KOUNT=0
      CALL REREAD (5)
C
C     READ A DATA CARD
C
   12 READ (5,510,END=2000)IPEN,ITEST,ICM,IDIR,ACC,VEL,DEC,NREC,RIL,FL,
     1                    MODE,AMP,FREQ,IO,RKV,RKA
  510 FORMAT (I4,I3,2I2,3F5.2,I4,F5.1,F6.2,I2,2F5.2,I4,2F6.3)
```

```
C
C     TEST TO SEE IF DATA CARD READ HAD DELTA T
C
      IF (IREP .EQ. 1129) GO TO 17
C
C     REREAD DATA CARD AS THIS IS A CARD WITH DELTA T AND
C     NINT=1/DELTAT
C     NAVE=1000*DELTAT
      CALL XBACK
      READ (5,500) DELTAT,NINT,NAVE
500   FORMAT (10X,F10.0,2I10)
C
C     WRITE DELTAT, NINT, NAVE
C
      WRITE (2,210) DELTAT,NINT,NAVE
210   FORMAT (10X,'DELTAT=',F10.3/
     1        10X,'NINT=1/DELTAT=',I5/
     2        10X,'NAVE=1000*DELTAT=',I5//)
      NJ=6*NAVE
      GO TO 12
C
C     DATA CARD READ HAS IDENTIFICATION AND PARAMETERS FOR A TEST
C
C     WRITE THE IDENTIFICATION AND PARAMETERS FOR A TEST ON A CHECK LIST
C
17    WRITE (2,220)
220   FORMAT (10X,'ITEST,ICM,IDIR,ACC,VEL,DEC,NREC,RIL,FL,MODE,AMP,FREQ,
     1ID,RKV,RKA'/)
      WRITE (2,230) ITEST,ICM,IDIR,ACC,VEL,DEC, NREC,RIL,FL,MODE,AMP,
     1              FREQ,ID,RKV,RKA
230   FORMAT (10X,0PI13,2I2,3F5.2,I4,F5.1,F6.2,I2,2F5.2,I4,2F6.3)
      RT=NREC
C
C     READ THE FIRST RECORD FROM A FILE (TEST) ON MAG TAPE
C
      CALL READRC(IDATA,NB)
      WRITE (2,250) ITEST,ID,NB
250   FORMAT    (10X,'ITEST=',0PI10,'    ID=',I10,'    NB=',I10)
C
C     TEST THE AGREEMENT OF THE ID DATA FROM CARDS AND TAPE
C
      IF (ID .NE. IDATA(1)) GO TO 900
      IF ( NREC .NE. IDATA(2)) GO TO 910
      IF (NCHN .NE. IDATA(3)) GO TO 920
      IF (NWRD .NE. IDATA(4)) GO TO 930
C
C     DRAW GRID WITH THE AXES
C     PRINT AXES TITLES, SCALE NUMBERS, AND TEST NUMBER
C
      CALL GD1129
      NTIME=NINT*NREC
C
C     WRITE THE HEADING FOR THE FIRST PAGE OF TABLE:
C     "EXPERIMENTAL DATA"
C
      CALL HDG1
      KOUNT=KOUNT+23
C
```

```
C     SET UP A COUNTER TO SERVE AS A TIME BASE
C
      ICOUNT=0
C
C     READ, AVERAGE, CALCULATE, AND WRITE TABLE FOR ALL BUT FIRST RECORD
C     IN A FILE (TEST)
C
      DO 100 I=1,NREC
      CALL READRC(IDATA,NB)
      WRITE (2,250) ITEST,ID,NH
   10 JSLOT=0
      DO 20 J=1,NINT
C
C     THIS PROGRAM USES THE FIRST FIVE OF THE SIX CHANNELS
C
      DO 20 K=1,5
      XX=0.
      DO 25 L=1,NAVE
      XX=XX+IDATA((J-1)*NJ+K+(L-1)*NCHN)
   25 CONTINUE
      JSLOT=JSLOT+1
      JDATA(JSLOT)=XX/NAVE
   20 CONTINUE
      J=1
C
C     CONVERT AVERAGED DATA, ADC WORDS, INTO VOLTAGES
C
   30 DO 35 K=1,5
      IC(K)=J+K-1
      VC(K)=P1*JDATA(IC(K))
   35 CONTINUE
C
C     CONVERT VOLTAGES INTO ENGLISH UNITS
C     AND APPLY CORRECTIONS OF MARCH 8, 1978
C     BKV AND BKA ARE PROVIDED AS INPUT
C
      X=BKX*VC(2)
      OANGL=BKO*VC(3)
      A=BKA*VC(4)
      V=BKV*VC(5)
      OAR=OANGL/57.296
      T=BKT*VC(1)-.0563
      F=(.001654/12.)*COS(OAR)*(2.*PI*FREQ)**2
      T=T-F
C
C     TO CONVERT ENGLISH UNITS INTO METRIC UNITS
C
      TM=PLBG*T
      XM=FICM*X
      AM=FICM*A
      VM=FICM*V
      COUNT=FLOAT(ICOUNT)/NINT
      IF (COUNT .GT. 0.) GO TO 40
      RCOT=COUNT
      PUNIT=0.
C
C     PRINT DATA FOR RCOT=0.
C
```

```
      WRITE (6,600)      RCDT,RUNT,OANGL,T,X,V,A,TM,XM,VM,AM
600   FORMAT (T6,2(0PF9.3) ,F8.1,1PE13.3,0PF9.2,6(1PE13.3))
      KOUNT=KOUNT+1
      GO TO 60
C
C     START RUN TIME COUNT, RUNT, WHEN TACHOMETER STARTS
C     AND END RUNT WHEN IT STOPS
C
40    CONTINUE
      ABSV=ABS(V)
      IF (ABSV .LE. 0.025) FLIP=0.
      IF (ABSV .GT. 0.025) FLIP=1.
      IF (FLIP .GT. 0.) GO TO 50
      BASE=COUNT
50    CONTINUE
C
C     CALCULATE SUBSEQUENT VALUES OF RCDT AND RUNT
C
      RUNT=FLIP*(COUNT-BASE)
      RCDT=COUNT
      IF (KOUNT .EQ. 57) KOUNT=1
      IF (KOUNT .EQ. 1) GO TO 55
      GO TO 58
55    CALL HDG2
      KOUNT=11
C
C     PRINT THE DATA
C
58    WRITE (6,600)      RCDT,RUNT,OANGL,T,X,V,A,TM,XM,VM,AM
      KOUNT=KOUNT+1
60    ICOUNT=ICOUNT+1
C
C     STORE VALUES OF TENSION, LBS AND TIME FOR PLOT
C
      TPLOT(ICOUNT)=T
      TIME(ICOUNT)=RCDT
      J=J+5
      JTEST=NINT*5
      IF (J .GT. JTEST) GO TO 100
      GO TO 30
100   CONTINUE
C
C     END OF A FILE
C
      CALL READRC(IDATA,NB)
      WRITE (2,250) ITEST,ID,NB
C
C     TEST FOR END OF FILE
C
      IF (NB .NE. 0) GO TO 940
C
C
C     PLOT TENSION, LBS VS TIME, SEC FOR A TEST
C
      CALL XYPLOT(ICOUNT,TIME,TPLOT,-15.,135.,0.,5.,DOC,-1)
C     READ NEXT VALUE OF DELTAT AND PARAMETERS FOR NEXT TEST
C
      GO TO 10
```

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```
C
C     ALL FILES  (TESTS) ON THE TAPE HAVE BEEN READ
C
2000  STOP
C
C     ERROR MESSAGES
C
900   WRITE (6,690) ITEST,ID,IDATA(1)
690   FORMAT (//10X,'ID SHOULD EQUAL IDATA(1).'/
     1        10X,'ITEST=',0PI5,'   ID=',I10,'   IDATA(1)=',I10)
      STOP
910   WRITE (6,691) ITEST,ID,NREC,IDATA(2)
691   FORMAT (//10X,'NREC SHOULD EQUAL IDATA(2)'/
     1        10X,'ITEST=',0PI5,'   ID=',I5,'   NREC=',I10,'   IDATA(2)=',
     2        I10)
      STOP
920   WRITE (6,692) ITEST,ID,NCHN,IDATA(3)
692   FORMAT (//10X,'NCHN SHOULD EQUAL IDATA(3).'/
     1        10X,'ITEST=',0PI5,'   ID=',I5,'   NCHN=',I10,'   IDATA(3)=',
     2        I10)
      STOP
930   WRITE (6,693) ITEST,ID,NWRD,IDATA(4)
693   FORMAT (//,10X,'NWRD SHOULD EQUAL IDATA(4).'/
     1        10X,'ITEST=',0PI5,'   ID=',I5,'   NWRD=',I10,'   IDATA(4)='
     2        ,I10)
      STOP
940   WRITE (6,694) ITEST,ID,NB
694   FORMAT (//,10X,'SHOULD BE END OF FILE WITH NB=0.'/
     1           10X,'ITEST=',0PI5,'   ID=',I5,'   NB=',I10)
      STOP
      END
      SUBROUTINE HDG1
C     2/2/78
C     GALCIT REPORT HSWT-1129
C     W.O. 97683
C     TO PUT A HEADING ON THE FIRST PAGE OF EACH TEST NO. OF
C     EXPERIMENTAL DATA
C
C
      COMMON / SHDG2 / IPAGE
      COMMON/  SHDG1/ITEST,ICM,IDIR,ACC,VFL,DFC,RT,RIL,FL,MODE,AMP,FREQ,
     1ID,NREC,RKV,RKA
      DIMENSION ICMH(2,2)
      DATA ICMH(1,1),ICMH(1,2),ICMH(2,1),ICMH(2,2)/'NYLO','N   ','RUBB',
     1'ER  '/
      DIMENSION IDIRH(3,2)
      DATA IDIRH(1,1),IDIRH(1,2),IDIRH(2,1),IDIRH(2,2),IDIRH(3,1),IDIRH(
     13,2)/'PAY-','OUT ','REEL','-IN ','STAT','IC  '/
      DIMENSION MODEH(2,2)
      DATA MODEH(1,1),MODEH(1,2),MODEH(2,1),MODEH(2,2)/'DYNA','MIC ','ST
     1AT','IC  '/
      WRITE (6,600)
      WRITE (6,601)
      WRITE (6,602) ITEST,(ICMH(ICM,J),J=1,2),(MODEH(MODE,J),J=1,2),ID,
     1              (IDIRH(IDIR,J),J=1,2),AMP,NREC,ACC,FREQ,VFL,DFC,RKV,
     2              RT,RKA,RIL,FL
600   FORMAT (1H1,/,T2,'GALCIT REPORT HSWT-1129',T118,'PAGE'/)
601   FORMAT (T59,'EXPERIMENTAL DATA'//T48,'VARIABLE LENGTH CABLE SYSTEM
```

```
      15    1HICS'/)
  602 FORMAT (T10,'TEST NO. ',0PI3,5X,'INCH PARAMETERS
      1          OSCILLATOR PARAMETERS                    DATA PARAMETERS'/
      2              T31,'CABLE MATERIAL ....... ',2A4,9X,'MODE ..............
      3',2A4,9X,'ID    =   ',I3/
      4              T31,'DIRECTION ........... ',2A4,9X,'AMPLITUDE, INCH ...
      5',F6.2,11X,'NREC =   ',I3/
      6              T31,'ACCELERATION, FPS2 ... ',F6.2,11X,'FREQUENCY, HZ ....
      7 ',F6.2,11X,'NCHN =      6'/
      8              T31,'VELOCITY, FPS ........ ',F6.2,48X,'NWRD =  6000'/
      9              T31,'DECELERATION, FPS2 ... ',F6.2,48X,'KV   =  ',1PE9.3/
      1              T31,'RUN TIME, SEC ........ ',0PF6.2,48X,'KA    =  ',1PE9.3
      2            /T31,'INITIAL LENGTH, FT ... ',0PF6.2/
      3              T31,'FINAL LENGTH, FT ..... ',0PF6.2///)
      IPAGE=1
      CALL HDG2
      RETURN
      END
      SUBROUTINE HDG2
C     2/2/78
C     GALCIT REPORT HSWT-1129
C     W.O. 97683
C     TO PUT A HEADING ON THE EACH PAGE AFTER THE FIRST OF
C     EACH TEST NUMBER OF EXPERIMENTAL DATA
C
C
      COMMON / SHDG2 / IPAGE
      IF (IPAGE .EQ. 1) GO TO 10
      WRITE (6,600)
      WRITE (6,601)
      WRITE (6,602)
  600 FORMAT (1H1,/T7,'GALCIT REPORT HSWT-1129',T118,'PAGE'/)
  601 FORMAT (T59,'EXPERIMENTAL DATA'//T48,'VARIABLE LENGTH CABLE SYSTEM
     'S DYNAMICS'/)
  602 FORMAT (T35,'-------------- ENGLISH UNITS  --------------',3X,
      1          '----------------- METRIC UNITS  ---------------'/
      2              T2,4X    ,4X,'RCDR',6X,'RUN',4X,'OSCL.',5X,'TENSION',3X,
      3              'LENGTH',4X,'VELOCITY',6X,'ACCEL.',7X,'TENSION',6X,
      4              'LENGTH',6X,'VELOCITY',6X,'ACCEL.'/
      5              T3,3X    ,4X,'TIME',5X,'TIME',4X,'ANGLE'/
      6              T11,'SEC',6X,'SEC',5X,'DEG',8X,'LBS',7X,'FT',
      7              7X,'FT/SEC',5X,'FT/SEC/SEC',7X,'GRAM',9X,'CM',9X,'CM/SEC',
      8              5X,'CM/SEC/SEC'/)
      GO TO 20
   10 WRITE (6,602)
   20 IPAGE=0
      RETURN
      END
      SUBROUTINE GD1129
C     3/2/78
C     GALCIT REPORT HSWT-1129
C     W.O. 97683
C     TO BE USED FOR TENSION VS TIME PLOTS
C     DRAWS THE AXIS LINES AND LINES .5 INCH APART TO FORM GRID
C     PRINTS THE AXES TITLES AND SCALE NUMBERS ON THE INCH LINES
C     PRINTS TEST NUMBER ON EACH PLOT
C     THE TIME AXIS WILL ALWAYS BE THE SAME LENGTH, I.E. 12 INCHES LONG.
C     TO ACCOMMODATE A MAXIMUM TIME OF 120 SECONDS
```

```
C
      COMMON/SHOGI/ITEST,ICM,IDIR,ACC,VEL,DEC,RI,RIL,FL,MODE,AMP,FREQ,ID
     1,NDEC,RKV,RKA
      DIMENSION XLINE(25),YLINE(21)
      DO 10 I=1,25
      XLINE(I)=1.5+.5*(I-1)
   10 CONTINUE
      DO 15 I=1,21
      YLINE(I)=.5*(I-1)
   15 CONTINUE
C
C     PRINT TIME AXIS TITLE
C
      CALL SYSSYM (10.42,-.4,.15,'TIME, SEC',9,0.)
      XB=XLINE(1)
      XE=XLINE(25)
C
C     DRAW THE TIME AXIS LINE
C
      DO 20 I=1,2
      Y=YLINE(1)+(I-1)*.008
      CALL SYSPLT(XB,Y,3)
      CALL SYSPLT(XE,Y,2)
      CALL SYSPLT(XE,Y,3)
   20 CONTINUE
C
C     PRINT THE FIRST TENSION AXIS SCALE LABEL
C
      CALL SYSSYM (1.25,0.,.1,'0',1,0.)
C
C     DRAW THE HORIZONTAL GRID LINES AND
C     PRINT THE TENSION AXIS SCALE NUMBERS
C
      DO 30 I=1,20
      Y=YLINE(I+1)
C
C     DRAW A HORIZONTAL GRID LINE
C
      CALL SYSPLT(XB,Y,3)
      CALL SYSPLT(XE,Y,2)
      CALL SYSPLT (XE,Y,3)
C
C     TEST I,   EVEN OR ODD
C
      I2=I/2
      RI2=I/2.
      IF ((RI2-I2) .GT. .000001) GO TO 30
C
C     I IS EVEN
C     PRINT TENSION AXIS SCALE NUMBER
C
      RNUM=I/4.
      IF (I .EQ. 20) Y=Y-.01
      CALL RPTNUM(1.24,Y,.1,RNUM,'(F3.1)',0.)
   30 CONTINUE
C
C     PRINT THE TENSION AXIS TITLE
C
```

```
      CALL SYSSYM (1.,6.5,.15,'TENSION, LBS',12,90.)
C
C     DRAW THE TENSION AXIS LINE
C
      Y2=0.
      YE=YLINE(21)
      DO 40 I=1,2
      X=XLINE(1)+(I-1.)*.008
      CALL SYSPLT(X,Y2,3)
      CALL SYSPLT(X,YE,2)
      CALL SYSPLT(X,YE,3)
   40 CONTINUE
C
C     PRINT THE FIRST TIME AXIS SCALE LABEL
C
      CALL SYSSYM (1.5,-.15,.1,'0',1,0.)
C
C     DRAW THE VERTICAL GRID LINES AND
C     PRINT THE TIME AXIS SCALE NUMBERS
C
      Y=YLINE(1)
      YE=YLINE(21)
      DO 50 I=1,24
      X=XLINE(I+1)
C
C     TEST IF I IS EVEN OR ODD
C
      I2=I/2
      RI2=I/2.
      IF ((RI2-I2) .LT. .000001) GO TO 45
C
C     I IS ODD
C
      GO TO 48
C
C     I IS EVEN
C
   45 PNUM=10.*(I/2.)
      XTIME=X-.2
C
C     PRINT A TIME SCALE NUMBER
C
      CALL PRINUM (XTIME,-.15,.1,PNUM,'(F5.1)',0.)
C
C     I IS EVEN OR ODD
C     DRAW A VERTICAL GRID LINE
C
   48 CALL SYSPLT (X,Y,3)
      CALL SYSPLT (X,YE,2)
      CALL SYSPLT (X,YE,3)
   50 CONTINUE
C
C     PRINT THE TEST NUMBER
C
      CALL SYSSYM (11.5,10.10,.15,'TEST NO. ',9,0.)
      CALL PRINUM (12.65,10.1,.15,ITEST,'(I2)',0.)
      RETURN
      END
```